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THE SHOCK AND VIBRATION DIGEST

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SVIC NOTES

MEASURED DATA AND TAILORING

The Institute of Environmental Sciences and the Defense Material Specification and Standards Office recently co-sponsored the first of a series of conferences on tailoring environmental design and test requirements. Many worthwhile findings and recommendations were made, and some unresolved issues were identified. Additional issues arose as a result of the discussions of the working group reports on the last day of the conference. Time does not permit a complete review of this conference; it will appear in a future issue of this publication. However, the availability of measured environmental data was one of the issues that arose during the conference, and it will be discussed briefly.

All of the working groups recognized the importance of access to measured environmental data, or to some type of environmental data bank, in their recommendations and findings. One working group recommended funding a program to measure environmental data on those vehicles where it is not available. Questions on environmental data following the working group reports included:

- What are the sources of environmental data?
- Assuming some type of data bank was established, what form should it take? Should it be a large data bank, or should it be a network of smaller data bases interconnected by computers?
- How useful, or valid, are data published in technical reports or technical journals?

The issue of environmental data alone raises many questions in addition to those listed above. For example, how long are measured data useful or valid? What percentage of time is it possible to obtain data measured in the exact location of interest on the platform?

An even more important issue, and one which is closely related to measured environmental data, is how to translate the measured data into meaningful design or test requirements. Appendix 1 to Method 514.3, in MIL-STD-810D, provides some guidance on translating field data; but judging from the discussions, and the many questions raised on this subject during the conference, more guidance is needed.

R.H.V.

EDITORS RATTLE SPACE

PEAK vs RMS VIBRATION MEASUREMENTS

Since the mid 1960s engineers have sought a single index, based on a vibration measurement, that would be indicative of machinery condition. Although peak and RMS (true) vibration measurements have been proposed for this index, controversy over the suitability of one or the other has delayed a final decision. A panel session at a recent Vibration Institute meeting shed some light on the issue but did not resolve it.

If the controversy is to be resolved in favor of either index, values of the index will have to be related to damage levels of equipment. During the last 20 years no concrete work has been published on the relationship between either index and machine condition. Arguments have been based on single examples, sometimes contrived to make a case for one of the measures. I suspect that, if the truth were known, neither index would satisfy all requirements because of the varied nature of equipment. On the other hand, it seems to me that either index could be used if suitable calibration and study were undertaken: changes in the index in response to condition changes are the most important criteria. Of course we would like to select the index that shows the best sensitivity -- the largest change of index for smallest change in condition.

It is certain that in order for the U.S. to move ahead on this issue, we will have to adopt one or the other index, either peak or RMS. Most U.S. engineers favor peak measurements; it would, therefore, seem natural to choose that index. However, in an attempt to maintain consistency with the International Standards Organization (ISO), the American National Standards Institute (ANSI) has tried to adopt the RMS measure. This action has been subject to subtle resistance with the result that U.S. engineers have no standard measure and cannot help but be confused when selecting meters for measurement.

Wouldn't it be better to adopt the peak measure even if it means breaking with the ISO, and see how it works? Wouldn't the adoption of one index be better than this continuous and long standing controversy which has gone on since the original ISO standards on machinery were adopted?

R.L.E.

HARDWARE AND SOFTWARE SELECTION FOR EXPERIMENTAL MODAL ANALYSIS

C.W. de Silva*

Abstract. Commercially available experimental modal analysis systems typically consist of an FFT analyzer, a modal analysis processor, a graphics terminal, and a storage device. Digital plotters, channel selectors, printers, hard copy units, and other accessories can be interfaced, and the operation of the overall system can be coordinated through a host computer to enhance its capability. The selection of hardware for a particular application should address specific objectives as well as hardware capabilities. Software selection is equally important. Proper selection is difficult unless the underlying theory is understood. In particular, determination of transfer functions via FFT analysis; extraction of natural frequencies; modal damping ratios and mode shapes from transfer function data; and the construction of mass, stiffness, and damping matrices from modal data should be considered. The paper addresses these issues. Four commercially available modal analysis systems are considered in a comparative evaluation.

In today's industry dynamic testing is being extensively incorporated into the design development, quality control, and qualification of products. A wide spectrum of devices and components ranging from large missiles, reactor coolant loops, and automobiles to delicate sensors, transducers, and microprocessor modules is tested in this manner. The primary objective of testing is to determine the dynamic behavior of the test object. This information can be used for fault diagnosis, design improvement, and evaluation of the operational capability of a system.

Dynamic tests typically involve applying a measured forcing excitation along a natural direction (degree of freedom) of the system and measuring the system response at that location as well as at other critical degrees of freedom. The wide choice of forcing excitations available -- impulse, sine sweep, sine dwell, sine beats, narrow-band random, and broadband random -- depend on the source of excitation. An instrumented hammer is used in impact (bump) testing. A portable shaker, typically electromagnetic, or a large shaker table, typically hydraulic, can be employed to provide the forcing excitation in single frequency, multi-frequency, or random testing [1].

Analyzing the measured response signals (time histories) allows determination of a variety of frequency domain and time domain information. In experimental modal analysis this information primarily consists of natural frequencies, modal damping, and mode shapes. If an adequate number of degrees of freedom is monitored during testing, it is possible to determine a complete dynamic model for the system in the time domain; specifically, mass matrix, stiffness matrix, and damping matrix can be extracted from test data.

This paper discusses several basic issues that should be considered in selecting a commercial stand-alone modal analysis system, from the point of view of hardware and software capabilities. Background theory pertaining to today's modal analysis software is introduced at the outset because it is important in understanding the functional operation of modal analysis systems.

ELEMENTARY THEORY OF EXPERIMENTAL MODAL ANALYSIS

The primary objective of experimental modal analysis is to extract natural frequencies, modal damping, mode shapes, mass matrix, stiffness matrix, and damping matrix of a dynamic system from a set of measured responses at crucial degrees of freedom (d.o.f.) for a known excitation applied at one of them at a time.

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Assume that the test object can be represented by an n-degree-of-freedom lumped-parameter model

$$\underline{M}\,\ddot{\underline{y}} + \underline{D}\,\dot{\underline{y}} + \underline{K}\,\underline{y} = \underline{f}(t) \qquad (1)$$

The nxn matrices $\underline{M}$, $\underline{D}$, and $\underline{K}$ are mass matrix, damping matrix, and stiffness matrix respectively. The forcing input vector is $\underline{f}(t)$, and $\underline{y}$ is the corresponding response. Note that, during testing, only one element of the vector $\underline{f}(t)$ is nonzero. It is customary to assume that the energy dissipation can be modeled by viscous proportional damping, so that normal (real) modes exist. This assumption can be relaxed eventually by incorporating complex modes. Proportionally damped systems, in the absence of forcing excitations, can be excited by a suitable initial condition so that all degrees of freedom move in proportion at a fixed frequency. This fixed proportion, which can be represented by a vector of arbitrary scale, describes a mode shape, and the associated frequency is the natural frequency of that mode.

Assume that each degree of freedom has an associated inertia (mass) element. This means that the system does not possess static modes (or residual flexibilities). If static modes are indeed present, they can be accounted for by assigning relatively large natural frequencies to the corresponding modes in the present formulation. Rigid body modes (or zero-natural-frequency modes) can be directly incorporated. An n-degree-of-freedom system has n modes. The corresponding mode shape vectors are linearly independent in the present formulation. The matrix of mode shape vectors, or modal matrix, normalized with respect to the mass matrix is given by

$$\underline{\Psi} = [\underline{\psi}_1, \underline{\psi}_2, \cdots, \underline{\psi}_n] \qquad (2)$$

The modal matrix is nonsingular in this case. Because the transformation

$$\underline{y} = \underline{\Psi}\,\underline{q} \qquad (3)$$

diagonalizes equation (1) into a set of simple oscillator equations, it follows that the input-output transfer function matrix $\underline{H}(j\omega)$ can be expressed as

$$\underline{Y}(j\omega) = \underline{H}(j\omega)\,\underline{F}(j\omega) \qquad (4)$$

with j denoting the imaginary unity $\sqrt{-1}$ and

$$\underline{H}(j\omega) = \underline{\Psi} \begin{bmatrix} H_1 & & & \underline{o} \\ & H_2 & & \\ & & \ddots & \\ \underline{o} & & & H_n \end{bmatrix} \underline{\Psi}^T \qquad (5)$$

Each diagonal term H_i is a simple-oscillator transfer function given by

$$H_i(j\omega) = \frac{1}{[\omega_i^2 - \omega^2 + 2j\zeta_i\omega_i\,\omega]} \qquad (6)$$

Note that ω_i is the i th undamped natural frequency (in the time domain) and is approximately equal to the frequency at the i th resonance (in the frequency domain) for low damping. The modal damping ratio is denoted by ζ_i.

Equation (5) can be written in the scalar form as

$$H_{ik}(j\omega) = \sum_{r=1}^{n} \frac{(\psi_i\,\psi_k)_r}{[\omega_r^2 - \omega^2 + 2j\zeta_r\omega_r\,\omega]} \qquad (7)$$

in which ψ_i and the ψ_k are the i th and k th elements of the mode shape vector in the r th mode.

Symmetry and reciprocity. Note from equations (5) or (7) that the transfer function matrix is symmetric. This can be interpreted as Maxwell's principle of reciprocity. Specifically, in the frequency domain, the response at the k th degree of freedom when an excitation is applied at the i th degree of freedom is equal to the response at the i th degree of freedom when the same excitation is applied at the k th degree of freedom.

Extraction of mass, stiffness, and damping matrices. After the modal data have been experimentally determined, the time domain model, given by equation (1), is extracted (identified) by using the following relationships; they result from the transformation shown in equation (3).

The mass matrix is given by

$$\underline{M} = (\underline{\Psi}\,\underline{\Psi}^T)^{-1} \qquad (8)$$

The stiffness matrix is given by

$$\underline{K} = \left[\underline{Y} \begin{bmatrix} 1/\omega_1^2 & & & \underline{0} \\ & 1/\omega_2^2 & & \\ & & \ddots & \\ \underline{0} & & & 1/\omega_n^2 \end{bmatrix} \underline{Y}^T\right]^{-1} \tag{9}$$

and the damping (proportional) matrix is given by

$$\underline{D} = \left[\underline{Y} \begin{bmatrix} 1/(2\,\zeta_1\,\omega_1) & & & \underline{0} \\ & 1/(2\,\zeta_2\,\omega_2) & & \\ & & \ddots & \\ \underline{0} & & & 1/(2\,\zeta_n\,\omega_n) \end{bmatrix} \underline{Y}^T\right]^{-1} \tag{10}$$

Note that the middle matrices on the right-hand sides of equations (9) and (10) are diagonal. Furthermore, because matrix inversion is needed at this stage, the fact that the modal matrix is nonsingular is necessary to guarantee a feasible solution.

STEPS OF MODAL EXTRACTION

Two primary tasks are associated with the extraction of modal data from response measurements: fast Fourier analysis and modal analysis.

Fast Fourier analysis generates the system transfer functions (in the frequency domain); modal analysis utilizes these functions as input data to extract modal parameters and the time-domain model. Two physically distinct hardware units are usually employed for the two tasks. The computer that performs fast Fourier analysis is known as an FFT analyzer or simply, analyzer; it is typically a hardwired digital processor. The modal analysis is performed within the processor of the system computer, using software programs written for that purpose. Due to these functional distinctions in hardware and software, it is useful to understand the main steps involved in the modal data extraction process.

Step 1 Fourier transform, using FFT, the measured data signals (excitation signal at the i th degree of freedom, and the responses at k th degrees of freedom)

Step 2 Compute the power spectral densities $\Phi_{ii}(\omega)$ and $\Phi_{kk}(\omega)$ and the cross spectral densities $\Phi_{ik}(\omega)$

Step 3 Compute the transfer functions using

$$H_{ik}(j\omega) = \frac{\Phi_{ik}(\omega)}{\Phi_{ii}(\omega)}$$

and ordinary coherence functions using

$$\gamma_{ik}^{\;2} = \frac{|\Phi_{ik}|^2}{\Phi_{ii}\Phi_{kk}}$$

for all available combinations of i and k; check for symmetry when possible

Step 4 Pick the best transfer function on the basis of high coherence; i.e., close to unity

Step 5 Calculate the natural frequencies and modal damping ratios by curvefitting

Step 6 Use equation (7) to compute the modal matrix

Step 7 Use equations (8) - (10) to compute the mass, stiffness, and damping matrices

The first three steps are performed by the FFT analyzer; the results are down loaded to the modal analyzer and typically stored on a floppy disk. The last four steps are performed by the modal analyzer, which uses these transfer function data.

The FFT procedures for computing transfer functions from test data are described in standard literature [1-3]. It is known that the cross-spectral density method has the capability of filtering out measurement noise; it therefore yields more accurate results in general. The closeness of the coherence function to a uniform value of unity is a measure of the accuracy of the computed transfer function in a given frequency band. It is essential to use the most accurate transfer function in Step 4 because the accuracy of the natural frequencies (strictly speaking, resonant frequencies) and modal damping ratios estimated in Step 5 directly affect the rest of the results. A curve fitting technique is usually employed in extracting modal parameters. The technique involves representing the measured transfer function by an analytical expression. The two common methods of curve fitting are single-degree-of-freedom (d.o.f.) curve fit and multi-degree-of-freedom curve fit.

In the single d.o.f. curve fit each resonance of the measured transfer function is approximated to a simple oscillator. This approximation can be done in the time domain in terms of an impulse response function or a differential equation for the simple oscillator or in the frequency domain by using the transfer function

$$\frac{a_r}{[\omega_r^2-\omega^2+2j\zeta_r\omega_r\omega]}$$

one resonance at a time. The Argand, or Nyquist, curve fit method is a graphical single d.o.f. curve fitting method in which each resonance is fitted into a circle in the real-imaginary (complex) plane. The Nyquist plot for a simple oscillator with velocity as the output -- i.e., mobility function -- is a circle. In a multi d.o.f. curve fit the entire transfer function is fitted into a higher order model (i.e., many resonances simultaneously) either in the time domain or in the frequency domain using an expression of the form

$$H(j\omega) = \sum_{r=1}^{n} \frac{a_r}{[\omega_r^2-\omega^2+2j\zeta_r\omega_r\omega]}$$

In this case all resonances are considered simultaneously. It follows that the multi d.o.f. curve fit is more accurate but, at the same time, computationally more demanding.

It is not necessary to measure the complete set of n^2 transfer functions in the $\underline{H}$ matrix in order to determine the modal matrix. The symmetry suggests that we do not need more than 1/2 n(n+1) transfer functions. It is easy to show, however, that just n transfer functions are adequate for this purpose. A convenient choice would be to measure any one row or any one column of the $\underline{H}$ matrix. For example, if the k th column is measured (H_{ik} with i = 1, 2, . . ., n), by applying a forcing excitation at the k th degree of freedom and measuring the corresponding response signals at all degrees of freedom, the procedure for constructing the modal matrix would be as follows:

i. Examine the (diagonal) transfer function H_{kk}, curve fit it to equation (7), and determine the k th element of the n mode shape vectors; $(\psi_k)_1, (\psi_k)_2, \ldots, (\psi_k)_n$. This constitutes the k th row of the modal matrix.

ii. Examine the transfer function $H_{k+i,k}$ and from equation (7) determine $(\psi_{k+i}\ \psi_k)_1$, $(\psi_{k+i}\ \psi_k)_2, \ldots, (\psi_{k+i}\ \psi_k)_n$. This gives the k+i th row of the modal matrix; $(\psi_{k+i})_1$, $(\psi_{k+i})_2, \ldots, (\psi_{k+i})_n$.

iii. Repeat step (ii) for i = 1, 2, . . ., n−k, and for i = −1, −2, . ., −k+1.

The above procedure for determining the modal matrix reveals that it is in fact not essential to measure a complete row or a complete column of the transfer matrix. As long as a diagonal element -- a point transfer function or an auto-transfer function -- is measured, the remaining n-1 transfer functions can be chosen arbitrarily, provided all n degrees of freedom are covered as either an excitation point, a measurement location, or both. Note, however, that it is advisable to measure redundant transfer functions (those providing information that is already determined by previous measurements) as well. Such redundant data are useful for checking the accuracy of the modal estimates. Figure 1 shows three sets of transfer functions on the transfer function matrix. The first set is an example for the case in which redundant transfer functions are present. In the second set no redundant transfer functions are present, but the set is adequate to extract the modal matrix. The third set is clearly not adequate to determine the entire modal matrix.

In practice, the frequency response data for higher resonances are relatively less accurate. It is therefore customary, in most modal software, to extract modal parameters only for the first several modes. Then it is not possible to recover the mass, stiffness, and damping matrices. Even if these matrices were determined, their accuracy would be questionable unless great care is exercised to improve the accuracy at higher frequencies, due to their increased sensitivity to noise.

HARDWARE AND SOFTWARE SELECTION

The hardware structure of a typical modal analysis system is shown in Figure 2. Either the response measurements can be directly transmitted to the FFT analyzer in real time two signals at a time (in the dual-channel case) or all measurements can be first recorded on a multiple-track FM tape and subsequently fed into the analyzer through a multiplexor or channel selector. In the former case it is necessary to take the analyzer to the test site; in the latter case an FM tape recorder is needed at the test site. Modern FFT analyzers are as compact as the conventional tape recorders used in vibration testing; either instrument could be used with equal convenience. The main advantage of recording data on FM tape is that it is available in analog form, free of quantizing errors (depends on word size) and aliasing distortion [1], depending on sample period. Sophisticated analog filtering is often necessary, however, to remove extraneous noise entering from the recording process. The analog-to-digital converter (ADC) is usually an integral part of the analyzer. After the transfer functions are computed, they are stored on a floppy disk or sometimes on a hard disk or a tape cartridge. They constitute the input data for modal extraction. Some analyzers store data as the power spectral densities and the cross-spectral densities of measurements, from which transfer functions, coherence functions, and other spectral information can be instantly computed. Still other analyzers store data as Fourier spectra of the measurements from which spectral densities can be determined. Most analyzers have built-in screens to display such spectral data.

In principle, the same computer can be used for both FFT analysis and modal analysis. Historically, digital FFT analyzers were developed first as dedicated hardwired digital processors. Because there are numerous applications in which a stand-alone FFT analyzer becomes advantageous, most modal analysis systems come with a standard hardwired FFT analyzer unit and a separate processor for modal analysis. Geometric information regarding the test object -- specifically the coordinates of the n degrees of freedom in three dimension -- are supplied to the computer through the terminal keyboard. Typically

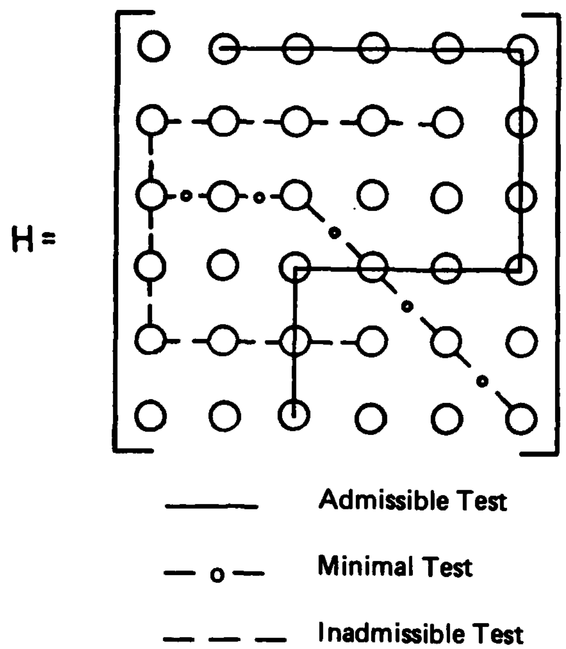

Figure 1. Schematic Representation of an Admissible Set of Transfer Functions

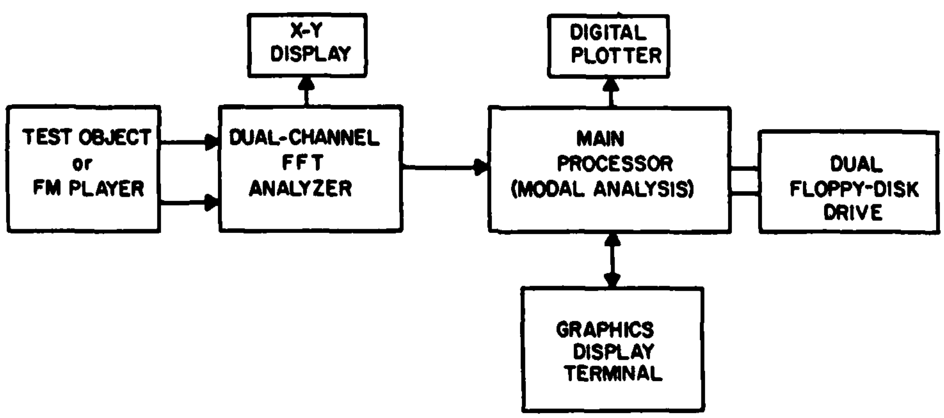

Figure 2. Hardware Configuration of a Commercial Modal Analysis System

data can be specified in cartesian, cylindrical, or spherical coordinates. For structures with repetitive geometry a pattern-entry capability can significantly reduce the data input time. Modal parameters are computed and stored on a floppy disk. This information can be displayed on a graphics screen or plotted on paper depending on the specific need.

Virtually all commercially available modal analysis systems include an IEEE 488 parallel interface bus as a standard or an option. It provides a convenient way for fast communication with a variety of digital devices. For example, the overall operation can be coordinated, and further processing can be carried out by a host computer. A schematic of this configuration is shown in Figure 3. Note that the modal analysis processor, graphics terminal, and storage device can be replaced by a commercial desk-top computer with an associated reduction in overall cost of the system. An alternative system configuration that is particularly useful in data transfer and communication from remote test sites is a voice-grade telephone line and a modem coupler to interface the FFT analyzer to the modal processor.

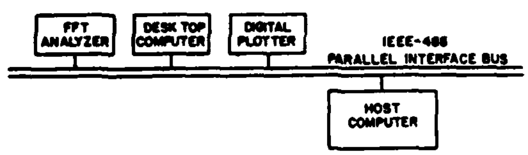

Figure 3. Typical Structure of a Modal Analysis System under Control of a Host Computer

Functional requirements. The first step in selecting a modal analysis system for a particular application is understanding the specific needs of that application. For industrial applications of modal testing the following requirements are typically adequate.

i. Acceptance of a wide range of measured signals having a variety of transient and frequency band characteristics

ii. Capability to handle up to 300 degrees of freedom of measured data in a single analysis

iii. FFT with frequency resolution of at least 400 spectral lines per 512

iv. Zoom analysis capability

v. Capability to perform statistical error-band analysis

vi. Static display and plot of mode-shape extremes

vii. Animated (dynamic) display of mode shapes

viii. Color graphics

ix. Hidden-line display

x. Multiple-pen color plotting and improved line resolution

xi. Capability to generate an accurate time-domain model (mass, stiffness, and damping matrices).

Comparative study. Four representative modal analysis systems are selected for a comparative study. We shall call them System A, System B, System C, and System D for convenience. This group is not intended to be exhaustive; there are other comparable systems. The availability of data has been the primary reason for these particular choices.

Several general comments can be made with respect to the functional requirements listed earlier. All four systems meet most of these requirements. The capability to accept a variety of measured signals depends primarily on the weighting window [1, 2] -- options available in the FFT analyzer. For example, the System D analyzer provides the conventional Hanning and box-car windows. In addition, it provides a flat-top window for accurate amplitude results and a half-Hanning window suitable for such transient data as impact-test data and for lightly damped responses having extensive end oscillations.

When the sample period (the time between two adjacent digital data simples) is ΔT, the maximum frequency that has any significance in digital Fourier analysis results is the Nyquist frequency (cut-off frequency) f_c [1]

$$f_c = \frac{1}{2\Delta T}$$

This relationship is known as the sampling theorem. Furthermore, if the record length used in a single FFT computation is T, it will require an input memory buffer with capacity for N samples (or N words if one sample is taken to occupy a word). The maximum number of spectral lines available in FFT results in this case is N/2. Unfortunately, due to aliasing distortion [1] the last several spectral lines (close to the maximum frequency) are not usable. The fraction of usable spectral lines determines the resolution of FFT results. Typically, with an input memory buffer having the capacity for 1024 sampled data points, about 400 usable spectral lines (the actual number of spectral lines being 512) can be generated. Zoom analysis [4] is used to improve spectral resolution. Zoom analysis uses a powerful coordinate transformation procedure in FFT to virtually eliminate the aliasing distortion in a specified band of frequencies. In effect, the same resolution (512 lines) is obtained even at the high frequency end of the spectrum. Statistical error band analysis [2] generates confidence intervals for spectral estimates such as frequency response functions, spectral densities, and coherence functions. None of the systems considered provides this capability. The general feeling is that such analyses are somewhat artificial in that an assumption is needed regarding the probability distribution of the measurement error.

The hidden-line capability for modal display is not found in typical modal analysis systems. The consensus is that this provision will require a significant effort of sophisticated programming (resulting in increased overall cost). The complexity arises when the object is viewed from variable directions in perspective; the hidden line configuration then varies and has to be continuously taken into account in the graphics software. The task becomes more complicated in animation. System B provides a color monitor that might be helpful in view contrast.

System D provides the capability to generate the structural mass and stiffness matrices. We have noted that, in order to make this computation possible, it is necessary to make the number of modes analyzed equal to the number of degrees of freedom in the test object. For example, for a 300 d.o.f. system it will be necessary to analyze all 300 modes in order to generate the 300 x 300 mass matrix and a stiffness matrix of the same size. This computational effort can often become futile for the following reasons:

a. estimated mass and stiffness matrices are sensitive to measurement noise

b. analysis of a large number of modes is an excessive burden on computer resources

c. low-coherent data are given the same significance as the more accurate data in these computations

The Table summarizes some basic data on the capabilities of the four systems studied. It is possible to identify a few relative merits and drawbacks. System C is compact and easy to operate even if the user has a marginal knowledge of theory and programming. A compatible eight-pen digital plotter can be used under system control. The cartridge drive is a slow (sequential) data storage device, but the relatively large memory in the computer (256 K bytes) offsets this deficiency. System D inherits the experience gained through its predecessor. The system has a faster and larger (30 M bytes) Winchester hard disk storage. Also, its analyzer provides several signal-dependent weighting windows. System B is the least expensive in a line of modal analysis systems marketed by the same manufacturer. A color monitor provided as an option with these systems is an attractive feature. System A provides an extensive data storage capability and speed. It carries a wealth of past experience in the area of digital signal analysis instrumentation. Several other options usually go in hand with modal analysis. These include the structural modification option that considers the sensitivity of modal parameters to changes in mass, stiffness, or damping in the system and the substructure linking option that in effect develops an overall model from test data obtained for two (or more) subsystems of the complete system. Only the modal analysis capability has been addressed in this paper.

CONCLUSIONS

Experimental modal analysis is being extensively used in industry to evaluate the dynamic performance of products during their design development, quality control, and qualification. Hardware and software selection for a stand-alone modal analysis system depends on the requirements of the specific application. A thorough understanding of the functional operation of the system and underlying theory can considerably aid this selection process.

Table. Comparative Data on Four Typical Modal Analysis Systems

DESCRIPTION	SYSTEM A	SYSTEM B	SYSTEM C	SYSTEM D
Number of Weighting Window Options Available	3	10	5	4
Analyzer Data Channels	2	2	2	2
Max. Degrees of Freedom per Analysis	750 @20 modes	450	725 @5 modes	750
Max. Number of Modes Analyzed	50 @250 d.o.f.	20	10 (typ.)	64
Multi-Degree-of-Freedom Curve Fitting	yes	yes	no	yes
FFT Resolution (usable spectral lines/512)	400	400	400	400
Zoom Analysis Capability in FFT	yes	yes	yes	optional
Statistical Error-Band Analysis	no	no	no	no
Static Mode-Shape Extremes	yes	yes	yes	yes
Animated Graphics Capability	yes	yes	yes	yes
Color Graphics Capability	no	yes	no	no
Hidden-Line Display	no	no	no	no
Eight-Pen Color Plotter	no	no	yes	no
Structural Mass and Stiffness Matrices	no	no	no	yes
Approximate Cost	\$55,000	\$32,000	\$46,000	\$75,000

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LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains an article about the analysis of turbomachine blades.

Dr. V. Ramamurti and Mr. P. Balasubramanian of the Indian Institute of Technology, Madras, India have written a review on the static and dynamic analysis of turbine blades and discs. Various formulations and solutions of linear and nonlinear vibrations of blades and discs are summarized.

ANALYSIS OF TURBOMACHINE BLADES -- A REVIEW

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Abstract. This literature review deals with the static and dynamic analysis of turbine blades and discs. The various formulations and solutions of linear and nonlinear vibrations of blades and discs are summarized. Experimental methods are also discussed.

Hundreds of articles have been published concerning the dynamic behavior of turbine blades. In this paper references published mostly between 1979 and 1983 are reviewed in the fields of stress and vibration analyses of blades and blade-disc interactions and experimental methods. This review includes both experimental and analytical investigations.

BLADES

Stress Analysis of Blades

Durocher and Kane [1] investigated blade deflections with a uniformly pretwisted finite element beam model. They checked previously obtained results with predictions from a three-dimensional finite element analysis; included were the effects of shear stress, axial-torsional coupling, and torsional stiffness. An analytical procedure based on the finite element method (FEM) was used to determine the blade stresses and deflections [2]. Ramamurti and Sreenivasamoorthy [3] used a three-dimensional 20 noded isoparametric finite element to analyze the rotating blade stresses for various pretwist angles, skew angles, breadth to length ratios, and breadth to thickness ratios of the blade. They compared these results with experimental results.

Blade loading for the input forces has been investigated with a NASTRAN finite element model [4]. Blade failures due to stresses have also been studied [5]. Stresses at the boundary of a blade have been predicted [6, 7] using elliptical equations and the successive approximate method. Nomograms and simple formulas are available for the determination of bending moment components in the blade [8, 9]. A computer program for the three-dimensional stress analysis of a blade using the finite element method is available [10].

Vibration Analysis

Linear analysis. Several references are available on linear analysis [11-14]. Leissa [12-14] discussed the merits and disadvantages of beam theory, plate theory, and shell theory with numerical results. In most recently published articles FEM has been used to solve blade vibration problems. The dynamic strength of group of blades has been investigated by considering the blade as a finite element beam model [15]. One vibration study of rotating beam included the effects of root radius, setting angle, and tip mass in the finite element model [16]. A triangular shell element model has also been used [17]. The results of this analysis showed the effects of geometric stiffness, rotational effects, aspect ratio, pretwist, taper, skew angle, and disc radius. Thomas and Sanbunch [18] extended finite element analysis to the behavior of rotating pretwisted blades of asymmetric cross section. Redesigning the vibrational characteristics of the blades was done with a NASTRAN program [19]. Variations due to transverse shear deformation and rotary inertia were pointed out [20].

A simple and powerful procedure has been used to calculate the frequencies of shallow shells [21]. A superparametric shell element is available to predict the vibrational characteristics of a real blade [22]. Yargicoglu [23] studied a substructure technique for composite rotor blades. The dynamic response of blades with a weighted edge has been analyzed for different end conditions and radii of curvature with the help of curved cylindrical finite elements [24]. Forced vibration analysis using a substructure technique has been implemented for rotating structures

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by treating arbitrary forces as a series of rotating forces [25].

Kinetostatic strains have been considered in derivations of the equations of motion for obtaining blade displacements, vibrational frequencies, and mode shapes [26]. The dynamics of packets of blades have been analyzed by incorporating responses due to the number of blades in the packet, stiffness and mass ratios, size and position of bracing wires, and rotating speed [27, 28]. A new FEM program called PVAST was used; it gives graphic results of dynamic stresses, displacements, frequencies, and mode shapes [29].

Many authors use different energy principles to deal with blade vibration problems. The accuracy of the energy method and transmissibility method have been compared [30]. Forced vibrational aspects of rotating blades have been studied using Lagrange's equations [31]. The effects of various parameters on blade dynamics have been studied using the Ritz method, Reissner's variational principle, Trefftz method, and modified lower bound method [32]. Results from the finite difference energy method have been examined with previously available results [33].

Rotating blade vibration has been considered using shallow shell theory and the Ritz method [34]; shallow shell theory has been compared with deep shell theory [35]. The potential energy method has been extended to blade vibration analysis [36-38]. The superiority of the Reissner method was pointed out; shear deformation, rotary inertia, speed of rotation, and stagger angle were accounted for. Nondimensional frequency parameters have been obtained for different aspect ratios, shallowness ratios, and thickness ratios [39]. Leissa addressed the problem of shallow shells by using the Ritz method with algebraic polynomial trial functions [40]. Vibration analyses for blades with and without camber are available [41].

A transfer matrix has been used to investigate the vibrational behavior of turbine blades [42]. Experimental and analytical results were also obtained for blades with shrouds by varying the number of blades in a group, the method of connection, geometrical tolerances, and centrifugal forces. Chiatti and Sestieri [43] used FEM in combination with transfer matrix method to study the free vibrations of turbine blades. Free and forced vibration analyses of closed periodic structures have been presented [44]. Non-massive blades of axial vents have been studied for different blade designs using a simple numerical procedure [45].

Flexural vibrations have been analyzed by treating the blade as a cantilever beam [46]. Subrahmanyam [47] has described the superiority of the Reissner method. Downs [48] has formulated the discretization technique for blade vibration and compared it with other techniques. Borishanski [49] stressed the vibration effects of fastening connectors on the blade. The beam analysis of blade vibration has been improved by accounting for earlier discrepancies [50].

Wood [51] brought out a new mathematical tool – the boundary integral technique – to investigate blade vibration. He incorporated torsional stiffness, warping stiffness, and shear center coordinates. The causes of gyroscopic forces and damping have been reported from beam analysis [52, 53]. It was found that coriolis acceleration due to gyroscopic motion of spinning rotors is creating new regions of instability [54]; also shown was the importance of second order resonance.

Hodges [55] presented a simple but efficient method for obtaining the fundamental frequency of blade vibration from the composite expansion technique. Leissa and Lee [56] used a numerical integration technique to solve the shallow shell analysis of blade. They also summarized the effects of rotational inertia, coriolis acceleration, variable curvature and thickness, and arbitrary quadrilateral planform. Free and forced vibrations and resonant stresses of rotating blades have been examined [57].

Nonlinear analysis. A number of articles have been published in the field of nonlinear vibration analysis of blades. Murthy and Hammond [58] used transmission matrices to linearize the blade equations of motion. Nonlinear differential equations have been converted into nonlinear algebraic equations and simplified by the method of iteration [59]. Venkatesan and Nagaraj [60] demonstrated the softening effect of large amplitude on flapwise frequency. Nonlinear blade vibration analyses have been discussed with the use of FEM [61-63].

Experimental Methods
Fluctuating blade stress measurements have been studied using spectral analysis [64]. Laser speckle photographs have been used to measure rotating blade stresses [65]. Kiraly [66] applied the digital system to almost 400,000 data points to investigate dynamic blade displacements. Advantages of the non-interferometry technique over the strain gage measurement method have been predicted [67]. Test results of dynamic stresses are available [68-71].

Glober and Maly [72] examined both the stress distribution and the frequency distribution with holographic interferometry, strain gauges, and piezoelectric gauges. Strain gauges and the telemetry technique have been used to measure dynamic stresses and natural frequencies [73]. Wachter and Beckmann [74] presented test results for the effects of exciting forces due to flow distortion and damping forces due to lacing wires on the blade stresses. Fu [75] explained the merits of applying holographic interference technique in combination with FEM. One advantage was the ability to estimate the correctness of results even at higher modes by using an infinite number of measuring points.

Finbow and Watson [76] have summarized different blade vibration measurement techniques. Shalabanov [77] revealed the limitations of the holographic interferometry method as opposed to a new technique for obtaining blade frequencies and nodes. Investigations of blade damage have been carried out with optical and scanning electron microscopes [78]. Egorov [79] has provided a spectral analysis of blade ring vibrations. Various kinds of measurement techniques have been reviewed and the merits and faults investigated [80, 81]. Blade vibrations due to rotating stall have been studied [82], and reduction in vibration amplitude due to lacing wire has been studied experimentally [83]. Leon [84] predicted the exact location of excessive blade vibration from the Doppler technique.

Shroud Stresses
The effects of shroud on blade vibrations has been studied experimentally and the results compared with FEM [85]. Shroud flange contact stresses have been analyzed, and severe conditions at which maximum stress occurs have been pointed out [86]. Stresses around shroud holes have also been analyzed [87]. It is of interest that a decrease in inclination of the shroud hole axis altered the maximum stress points and increased the maximum stress value. The strain freezing method has been used to study experimentally the behavior of stresses around the shroud hole; the results were compared with analytical results [88]. The vibration behavior of an assembly of shrouded blades has been investigated by studying the vibrational characteristics of the components [89]. Butt welding of long arc shrouds has been found to reduce dynamic stresses [90].

Effects of Damping
The effects of dry friction damping on blade vibration have been investigated in terms of anisotropic dry friction theory [91]. The system was treated as a lumped mass system, and a computer package was developed to study the blade to disc damping [92]. An experimental method for obtaining the friction coefficient was also outlined. An optimized system for the combined effects of dry friction damping and hysteresis damping at resonant condition has been suggested [93]. Non-aerodynamic damping effects have been discussed analytically as well as experimentally [94]. Griffin [95] has presented an efficient dry friction damping model and compared it with experimental results. Predictions of various damping parameters have been discussed [96, 97].

Griffin [98] studied the sensitivity of mistuning and its effect on slip force using modal analysis. Klompas [99] examined blade vibration due to elliptical whirling in viscous dampers and presented a method for obtaining whirl harmonics. An expression for blade motion that includes the effects of slip damping and hysteresis damping has been formulated [100]. A study of shrouds with corrugated bands has revealed the phenomenon of damping due to the bands [101]. The wire stiffness coefficient, influence of centrifugal force, position of wire, and magnitude of dynamic stresses have been determined and used to calculate the damping effect of blade wires [102]. Kapralov and Skvortsov [103] have discussed the vibrational effects of dry friction damping due to box-type dampers. Coulomb friction between the shroud ring elements has been studied to determine its effect on the vibrational characteristics of blades; anisotropic dry friction theory and FEM were used [104].

Forced vibration analysis for a compressor blade as a function of rotor speed and frequency of flow excitations has been carried out [105]. Lang and Nemat-Nasser [106] developed approximate step functions to investigate nonuniform blade vibrations; they discussed two examples and verified them with other results. A semi-empirical method has been used to measure the dynamic stresses of groups of blades affected by synphase and intra-packet vibrations [107]. Bending and torsional frequencies for lower modes have been calculated accurately [108]. Numerical methods have been formulated to predict the vibrational behavior of blades subjected to continuous erosion [109]. Nied [110] has determined the values of a set of frequency response functions from impulse excitation and used it to calculate modal parameters and hence vibrational aspects. A stationary functional method with normal modes has been utilized to approximate a nonlinear analysis of blade vibration; the effects of shear deformation, rotary inertia, and coriolis forces were included [111].

Dickerson [112] has summarized developments in turbine blade analysis and compared results from a test model and a theoretical analysis. Gudmundson [113] used a perturbation technique to investigate variations of natural frequencies as a function of blade geometry. The damping decay rate has been predicted accurately by using standing wave flutter analysis for tuned and mistuned blades [114]. The effects of interactions between bending and torsional motions of nonuniform blades were included [115]. Bendiksen and Friedmann [116] discussed blade flutter boundaries with bending-torsional coupling. Dynamic stresses and eigenvalues have been determined from the potential admission condition [117-119]. Wake-induced vibrations have been analyzed to determine dynamic stresses [120, 121]. The sequential optimization technique has been used to tune the natural frequencies of blades away from resonant conditions [122]. An optimum method for controlling the cross sections of blade to reduce weight has been outlined [123]. Life prediction theories have been used to evaluate blade tip durability from heat transfer and stress analysis [124]. Blade composite materials have been discussed for various influencing factors [125-127].

BLADE-DISC INTERACTIONS

Stress Analysis

Frictional forces between locking pieces significantly alter the contact stress distribution at the blade root [128]. Stress distribution for an orthotropic rotating disc of varying thickness has been investigated and compared with FE solutions [129, 130]. The centrifugal stresses in vanes and disc have been determined by treating unshrouded radial impellers as co-axial rings, and using the matrix method [131]. A shoulder at the root joint has been found to decrease dynamic loading and increase fatigue life [132]. Gamner [133] showed the invalidity of Tresca's yield criterion for a rotating disc from its discontinuity at the elasto-plastic interface. Rotating discs with linearly, exponentially, and hyperbolically varying thicknesses have been studied for strength analysis [134] using the matrix method. The matrix method has also been used to determine rhenomic and scleronomic components of inelastic deformation in an annular section of a disc [135]. Singh and Rawtani [136, 137] researched the stress distribution at the fir tree root fastening of turbine blades by simplifying the root as an assembly of steps. They incorporated the effects of centrifugal body force of the root, the force due to friction between the blade and disc steps, and the dissimilarities in the material properties of the blade and the disc. Kopecki and Walczak [138] have reported some important conclusions about the axisymmetry of the stress distribution of rotating discs made up of nonlinear material. A detailed study of stresses in rotating discs of variable thickness has been done using the finite different method [139]; included were thermal gradient and shrinkage effects.

Vibration Analysis

Lalanne [140] has presented references for the vibration control of blades; blade-disc interactions, axisymmetric structures, and rotors were considered. Ewins [141] has summarized fluid-structure interaction, vibration modes of bladed disc assemblies, tuned and mistuned assemblies, and flutter.

Numerous articles in which FEM was used to analyze blade disc interactions are available. Partington [142] extended the FEM to study the vibrating stresses and frequencies of pinned root blades and confirmed the results. The dynamics of compressor impellers have been studied [143]. Nagraj and Sahu [144] compared the Rayleigh Ritz method with the Galerkin technique in a study of torsional vibration of nonuniform turbine blades; also included was root flexibility. FEM and the holographic technique have been used to investigate the static, dynamic, and thermal loadings of a turbine impeller [145]. Kuo [146] modeled a blade-disc segment as a rotating symmetrical structure and studied the effects of coupled blade-disc resonance, the dissimilar behavior of blade groups, and the uncoupled blade or disc natural frequencies on the vibrational characteristics of the blade disc assembly. Efficient NASTRAN programs have been developed to analyze the aeroelastic and structural properties of bladed shrouded discs [147-155]. These programs also incorporate the effects of mistuning and tuning, forced vibration analysis, coriolis and centripedal accelerations, and flutter.

A special bladed disc element and a special shrouded blade element have been used to simplify the static and dynamic deflection analyses of blade [156]. Mindlin's thick-plate theory was used in a disc analysis with both annular and sector elements [157]; theoretical results from an eight noded, superparametric thick shell element analysis were compared with experimental results for a shrouded, bladed disk. Nigh and Olson [158] have reported the effects of damped and undamped transverse point loads in space-fixed coordinates; they also determined critical speeds in space-fixed coordinates. Singh [159] discussed the torsional vibrations of blades with root flexibility; he presented a correction factor for the fixed root frequency to account for root flexibility. Impeller blade frequencies, mode shapes, and stress distribution have been analyzed and verified with experimental results obtained by using semiconductor strain gauges and a mechanical telemetry system [160]. A model having a five-degrees-of-freedom subsystem has been used to study the dynamics of a bladed disc assembly; dry friction, structural damping, mistuning, and type of excitation were considered [161].

Loewy [162] used a classical structural dynamic analysis with Lagrange equations to discuss the response of bladed disc assemblies for a wide range of rotor flexibilities. Hunt [163] has suggested a transfer matrix method to study the in-plane vibrations of blades with known boundary conditions. Free and forced vibration characteristics of blades have been studied by applying the concept of rotationally periodic structure and the transfer matrix method [164]. An inertia and elastic hinge model has been used to consider flexibility of impellers [165].

Experimental Methods

Experimental results obtained from an image derotated holographic interferometry method have been checked with FEM solutions [166]. Mode splitting has been studied for mistuned bladed disc with the help of the holographic interferometry technique and strain gauges [167]. Speeds up to 13,000 RPM have been measured by utilizing eight-channel telemetry systems with holographic interferometry [168]. Experimental results of bench resonance are in good agreement with predicted frequencies [169]; included are the effects of in-plane inertial couplings in tuned and mistuned bladed disc assemblies. The fast Fourier transform technique has been used to investigate the vibrations of periodically symmetric structure such as bladed disc assemblies [170].

Jones [171] has formulated a simple discrete analytical model to predict the fundamental frequency of a blade with slip at the root; he verified the results experimentally. It has been shown that the fundamental frequency is a function of spin frequency for a rotating blade with an off-set root [172]. Singh and Rawtani [173] have modeled a blade with spring hinged-free end boundary conditions. Sollmann [174] has demonstrated a method for calculating the centrifugal force coefficient for rigidly mounted as well as flexibly mounted blades. Khader [175] has incorporated the effects of disc flexibility and shaft and bearing flexibilities in a bladed disc vibration analysis. A traveling wave solution has been used to obtain the dynamic characteristics of a shrouded bladed disc assembly [176].

Jendryschik used a co-rotating accelerometer to analyze the vibrations of rotating disc; he found that the mistuning of a bladed disc is caused by the irregularities of friction forces and by harmonic excitations [178]. Wildheim [179, 180] used the principle of dynamic substructures with free modes of a disc and the clamped free modes of a blade to predict the natural frequencies of a rotating bladed disc with lacing wire. Irretier [181] used the effects of variable thickness, centrifugal force, and the location of blades on the disc to determine the bending and torsional vibrations of a blade; direct integration techniques and the shooting method were used to solve the problem [182]. It has been shown that the effects of blade twist, shear deformation, rotary inertia for bending, centrifugal force, and stagger angle are significant [183]. Eigenvalues and mode shapes have been determined accurately for a flexibly attached blade using a direct numerical integration technique [184]. Numerous methods for finding modal quantities have been compared with component mode synthesis [185].

Effects of mistuning have been researched [186]. Partial detuning of a blade ring has been studied from a frequency diagram [187]. The blade response to the pliability of fixing has been evaluated and checked [188]. Significant minor resonances have been observed over and above the critical speeds of the disc [189]. The dynamic behavior of blades with a tree root has been investigated by a method of harmonic balance [190]; the reduced impedance method with substructure analysis was used [191]. Kuznetsov [192] has compared theoretical blade strength with actual values. The spline interpolation technique has been used to study the stress distribution and flexural vibrations of rotating annular discs of varying thickness [193]. Graphic results are available for the vibration analysis of rotating orthotropic discs having variable thickness and density along their radius [194]. Calculation of critical rotating speeds for laminated discs of different composite materials has been presented by Hinkel [195].

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BOOK REVIEWS

ADVANCES IN ELASTO-PLASTIC FRACTURE MECHANICS

L.H. Larsson, Editor
Applied Science Publishers, Ltd., London
1980, 428 pages

The book contains 17 papers that were presented at a seminar held at the Joint Research Centre of the Commission of the European Communities in Ispra (Varese) Italy in April, 1979. The papers form a framework for an advanced course in fracture mechanics.

The papers, in order of presentation, are:

1. "Macroscopic Aspects of Crack Extension," J.F. Knott (16 references)
2. "Microscopic Aspects of Crack Extension," J.F. KNott (23 references)
3. "The One-parameter Characterization Viewpoint in Fracture Mechanics," J. Carlsson (20 references)
4. "Experimental Techniques for the Determination of the Initiation of Failure," J.G. Blauel (5 references)
5. "Slow Stable Crack Growth and Unstable Fracture in the LEFM Regime," C.E. Turner (17 references)
6. "Determination of Fracture Toughness under Plane Stress Conditions by the R-Curve Method," B. Marandet et al (24 references)
7. "Application of J-R Curves to Slow Stable Crack Growth and Unstable Tearing in the Plastic Regime," C.E. Turner (30 references)
8. "Numerical Treatment of Crack Growth Problems," G. Rousselier (23 references)
9. "The EPRI Ductile Fracture Research Program," T.U. Marston (21 references)
10. "Micromechanisms of Slow Stable Crack Growth," D. Francois (44 references)
11. "Use of EPFM in Design," L.H. Larsson (39 references)
12. "The COD Design Curve," M.G. Dawes (38 references)
13. "A J-Based Design Curve," C.E. Turner (22 references)
14. "The Development and Application of the CEGB Two Criteria Approach for the Assessment of Defects in Structures," B.J.L. Darlaston (26 references)
15. "Incorporation of Residual and Thermal Stresses in Elastic-Plastic Fracture Mechanics Design," G.G. Chell (23 references)
16. "Numerical Aspects of Elastic-Plastic Fracture Mechanics Including 3-D-Applications," Y.W. Schmitt (18 references)
17. "Probabilistic Fracture Mechanics," J. Carlsson (22 references)

The first Knott paper sets forth various mechanical models for plastic flow crack propagation and an interpretation of some of these models. In the second paper Knott looks at the initial stages of plastic crack formation and propagation from a dislocation point of view. He describes some limitation on macroscopic analyses. The Carlsson paper examines the basis of elastic plastic fracture mechanics, including submicroscopic yielding behavior, and characterizes various crack tip field solutions by means of the J-integral. Blauel's paper contains a brief review of the more popular methods for determining the onset of crack propagation without a critical review of these methods. The review is reasonably up to date.

The second group of papers includes Turner's account of slow-stable crack growth in the linear elastic regime and the criterian ($dK/da > dR/da$) for the onset of unstable fracture. Turner's article contains an excellent critique of R-curve slope analysis problems, which are still unresolved. Marandet's paper describes various means for determination of R-curves, includes critiques of these methods, and recommends methods that should be employed. R-curve determinations are discussed in terms of their independence of certain test parameters. Marandet concludes that R-curve determinations are independent of specimen type, initial crack length, and loading method. Turner's second paper describes the application of J-R curves to slow, stable crack growth and discusses two theories for predicting unstable ductile tearing modes. Rousselier deals with numerical methods for determining crack behavior in the slow crack growth regime. The purpose of these analyses is to treat the problem in a realistic manner as opposed to the conservative linear elastic fracture mechanics approach.

Marston describes the EPRI funded elasto-plastic fracture mechanics program in progress at the time the book was written. The objectives and strategies of the program were stimulated by the Nuclear Power Industry regulations on system integrity and safety. Several tentative conclusions on the interrelationships among primary fracture mechanics parameters are set forth relative to ductile fracture.

Francois deals with some metallurgical aspects of slow stable crack growth. The paper seems to be disconnected, but, as Francois states, experimental evidence is scarce and contradictory.

The third section begins with a paper by Larsson on the application of elastic-plastic fracture mechanics in the design of structural components. He discussed most of the important methods for calculating the rates of crack growth under plastic flow conditions. It is a brief but excellent review. Following this paper, Dawes describes the use of one method, the COD design curve, and compares the results with those of experiments. Because the COD method is used extensively in design, it is comforting to note that the general safety factor of 2.5 on crack length is successfully applied to a wide variety of structural steels. Turner discusses the J-based design curve and includes the effect of residual stress and work hardening. He compares J-based and COD design curves and explores their separate relevances. The paper by Darlaston discusses the Central Electricity Generating Board two criteria approach to design known as the failure assessment route. This approach has been useful in the design of nuclear power plants in Great Britain.

Chell describes a method for including both residual thermal stresses in elastic plastic fracture mechanics (EPFM) design. Schmitt describes some numerical computational methods useful in EPFM design. Carlsson discusses some topics of the mixed subject of statistical fracture mechanics and elastic plastic fracture mechanics analyses. This final topic, which needs more elaboration than is given here, will eventually be adapted by most code agencies for advanced design, analysis, and retrofitting procedures.

The book is excellent. Both the text and figures are worth the time of the serious student.

K.E. Hofer
L.J. Broutman and Associates Ltd.
3424 South State Street
Chicago, IL 60616

DYNAMIC MECHANICAL DATA OF NON-REINFORCED PLASTICS

K. Lundin
Dept. of Technical Acoustics, Royal Institute of Technology, Stockholm, Sweden
1982, 137 pages

This paperback report the compilation of which was supported by the National Swedish Board for Technical Development is a compendium of information on the dynamic mechanical properties of plastics. Included are non-reinforced plastics with either little or no filler; the basis for their inclusion is their use as structural parts. Data are given for the temperature range from -40 to $120°C$; the range in loss factor is large enough to include low loss metals as well as high loss elastomers. The data are organized into four sections. The first section includes all the data compiled. Section two contains frequency dependent data (loss factor vs frequency, modulus vs frequency). Section three contains temperature-dependent data; i.e., loss factor vs temperature, modulus vs temperature. The results of dynamic measurements performed on sample materials obtained during the study are given in section four.

Many engineering designers are faced with the problem of controlling resonant vibration in structures and equipment. Damping materials are an important element in the analysis and design of structures to reduce vibration and noise problems. The dynamic properties of these materials in the temperature-frequency domain depend on a single compound variable that combines the effects of frequency and temperature. In view of the fact that all dynamic measuring techniques cannot be reliable over a broad range of frequencies and temperatures, a temperature-frequency equivalence is not only valuable but necessary for extrapolating data into regions in which the direct measurement of dynamic properties is either difficult or impossible. Because a variety of measurement techniques, instrumentation, and damping materials exist, the need for applying a temperature-frequency equivalence (in the form of a reduced temperature nomogram) is imperative. The author of this report, who is certainly aware of the use of the reduced temperature nomogram, has chosen to include plots of frequency- and temperature-dependent data instead of the reduced temperature nomogram; his reason is a lack of data for the nomogram. Formatting the data in this way could be potentially dangerous to the user of this report. The author should have included only material properties that are in a form usable by the designer; i.e., a reduced temperature nomogram for producing reliable data for engineering use. Otherwise, potential users can expect to be confused and possibly misled by the use of incomplete and unreliable data. If the author did not have the required number of data points to generate a reduced temperature nomogram, he should add qualifiers to the data he does include, so that the user is aware of the potential dangers that could result from extrapolation or interpolation.

V.R. Miller
5331 Pathview Drive
Huber Heights, OH 45424

ENGINE NOISE

R. Hickling and M.M. Camel, Editors
Plenum Publishing, New York, NY
1982, 497 pages, $62.50

The organizers and editors of the international symposium on "Engine Noise: Excitation, Vibration, and Radiation" held at the General Motors Research Laboratories on October 11-13, 1981, should be highly commended for, first of all, sponsoring the conference and, secondly, publishing the papers that were presented. This symposium contained timely work relative to current problems and concepts that are applicable to noise control problems not necessarily associated with engine noise. Papers on engine noise and its various aspects were prepared by authors from universities, industry, and government.

The four sections of the book correspond to sessions held during the symposium. The first section contains new work on excitation sources of engine noise -- including cylinder pressure pulsations, piston slap, gear noise excitation, and fuel-injection systems -- and their control. The session corresponding to this section was chaired by Theo Priede of the University of Southampton. The second section deals with transmission paths and structural vibrations of engines. Dick Lyon, Massachusetts Institute of Technology, headed the session. Topics included vibration transmission analysis, noise and vibration in linkages, engine structure vibrations, and finite element techniques to assess the noise of engine structures. The third session, chaired by J.Y. Chung of the General Motors Research Laboratories, was concerned with noise radiation from engine surfaces, including acoustic intensity measurements of engine noise and comparisons of different measurement approaches. Methods for computing engine noise surface acoustic radiation are presented as are numerical methods for acoustic problems. The final session, which was chaired by Jerry Manning of Cambridge Collaborative, Inc., described practical methods for reducing engine noise. This section presents methods for using enclosures for noise reduction and for modifying sources to alter noise and vibration mechanisms that cause problems.

Included at the end of each paper are the discussions that followed the presentations. In some cases written comments received from the audience were printed. The book contains a list of conference participants, an author and contributor index, and a subject index.

The concepts, techniques, and methods are presented in such a way as to make them valuable to those interested in noise control. This book should be of interest to those who work in noise control in the areas of community and factory noise and to those in the transportation industry.

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5331 Pathview Drive
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FINITE ELEMENT PRIMER

B. Irons and N. Shrive
Halsted Press, New York, NY
1983, 157 pages, $39.95

This book is of an elementary nature and is intended to acquaint the reader with finite elements (FE). The authors strive to make the text readable and humorous; the witty sayings should interest the reader. The first chapter begins with a definition of FE, how it works, its uses, and problems that can occur. According to the authors the book "is a planned procedure and explains in a fashion that one would speak to a class."

In the second chapter on the FE method, examples include a hanging cable, a membrane in tension, a spring-supported membrane, and a structural test rig. The chapter concludes with a method for solving FE equations and mentions the program FEMSKI.

Chapter three describes such fundamentals as strain energy, virtual work, and shape functions. The use of strain energy is discussed, and the Taig quadrilateral, the forerunner of the isoparametric element, is introduced. Lumped springs for integration, the stiffness matrix of the Taig quadrilateral, in-plane deflections, and a patch test for convergence are included.

Chapter four has to do with what good elements do. The shape functions of an eight-node rectangular element are used; the stiffness matrix is obtained by direct integration. The element must pass the patch test. The main problem is the false differentiation at the nodes due to incorrect loads at the nodes.

Chapter five has to do with what bad elements do. A 2x2 manual integration for an eight-node element could cause a singularly assembled stiffness matrix. The bending moments at the Gauss points are good even though the curved beam element is ill behaved. The mechanism of a bad element can be stabilized by neighboring elements.

The next chapter describes how metals deform. The authors describe stress/strain relationships, their assembly in matrix form, principal stresses and load paths, transformation of matrices, and simple numerical examples to determine eigenvalues and eigenvectors. In chapter seven the authors use a stress-deflection matrix transformation that involves the inverse Jacobian matrix to obtain the strain derivations in the Taig quadrilateral. The chapter concludes with an interesting discussion of shape function routine; examples of objects subjected to torsion, bending, pressure, and tension are given.

The next chapter warns the reader of some of the hazards of computers. Examples are wrong answers are illustrated by a simple cantilever, two ill-conditioned equations, and round off.

Chapter nine has to do with spurious side effects that can cause consternation to a user. The authors mention semiloof shell elements that have been used in a number of examples with excellent results. Refer to Dr. Iron's earlier book, Techniques of Finite Elements. The concluding chapter describes how elements warp and the shearing of beams.

This good book contains an excellent nomenclature section. The reviewer recommends it to the beginner who wants to read a novel text on finite elements.

H. Saunders
1 Arcadian Drive
Scotia, NY 12302

SHORT COURSES

SEPTEMBER

MACHINERY INSTRUMENTATION

Dates: September 12-14, 1984
Place: Calgary, Alberta, Canada
Objective: To provide an in-depth examination of vibration measurement and machinery information systems as well as an introduction to diagnostic instrumentation. The seminar is designed for mechanical, instrumentation, and operations personnel who require a general knowledge of machinery information systems. It is a recommended prerequisite for the Machinery Instrumentation and Diagnostics Seminar.

Contact: Bob Grissom, Customer Training Department, Bently Nevada Corporation, P.O. Box 157, Minden, NV 89423 - (702) 782-9315.

FIELD INSTRUMENTATION AND DIAGNOSTICS

Dates: September 18-21, 1984
Place: Edmonton, Alberta, Canada
Dates: December 3-6, 1984
Place: Houston, Texas
Objective: To provide a balanced introduction to diagnostic instrumentation and its applications for evaluating rotating machinery behavior. The seminar also covers fundamental rotating machinery behavior and some of the more common machinery malfunctions. It includes a lab session with workshops on data acquisition instrumentation, balancing, oil whirl/whip and rubs, and monitor system calibration.

Contact: Bob Grissom, Customer Training Department, Benley Nevada Corporation, P.O. Box 157, Minden, NM 89423 - (702) 782-9315.

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: September 24-28, 1984
Place: Ottawa, Ontario, Canada
Dates: October 15-19, 1984
Place: New York, New York
Dates: November 5-9, 1984
Place: San Francisco, California
Dates: February 4-8, 1985
Place: Santa Barbara, California
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos Street, Santa Barbara, CA 93105 - (805) 682-7171.

OCTOBER

VIBRATIONS OF RECIPROCATING MACHINERY

Dates: October 9-12, 1984
Place: Houston, Texas
Objective: This is a new course on vibrations of reciprocating machinery including piping and foundations. Equipment that will be addressed includes reciprocating compressors and pumps as well as engines of all types. Engineering problems will be discussed from the point of view of computation and measurement. Basic pulsation theory -- including pulsations in reciprocating compressors and piping systems -- will be described. Acoustic resonance phenomena and digital acoustic simulation in piping will be reviewed. Calculations of piping vibration and stress will be illustrated with examples and case histories. Torsional vibrations of systems containing engines and pumps, compressors, and generators, including gearboxes and fluid drives, will be covered. Factors that should be considered during the design and analysis of foundations for engines and compressors will be discussed. Practical aspects of the vibrations of reciprocating machinery will be empha-

sized. Case histories and examples will be presented to illustrate techniques.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

MACHINERY VIBRATION ANALYSIS

Dates: October 9-12, 1984
Place: Houston, Texas
Dates: November 27-30, 1984
Place: Lisle, Illinois
Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow-speed paper rolls.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

MACHINERY VIBRATION ENGINEERING

Dates: October 9-12, 1984
Place: Houston, Texas
Dates: November 27-30, 1984
Place: Lisle, Illinois
Objective: Techniques for the solution of machinery vibration problems will be discussed. These techniques are based on the knowledge of the dynamics of machinery; vibration measurement, computation, and analysis; and machinery characteristics. The techniques will be illustrated with case histories involving field and design problems. Familiarity with the methods will be gained by participants in the workshops. The course will include lectures on natural frequency, resonance, and critical speed determination for rotating and reciprocating equipment using test and computational techniques; equipment evaluation techniques including test equipment; vibration analysis of general equipment including bearings and gears using the time and frequency domains; vibratory forces in rotating and reciprocating equipment; torsional vibration measurement, analysis, and computation on systems involving engines, compressors, pumps, and motors; basic rotor dynamics including fluid film bearing characteristics, critical speeds, instabilities, and mass imbalance response; and vibration control including isolation and damping of equipment installation.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

ELECTROEXPLOSIVES DEVICES

Dates: October 16-19, 1984
Place: Philadelphia, Pennsylvania
Objective: Topics will include but not be limited to the following: history of explosives and definitions; types of pyrotechnics, explosives and propellants; types of EEDs, explosive trains and systems, fuzes, safe-arm devices; sensitivity and functioning mechanisms; output and applications; safety versus reliability; hazard sources; lightning, static electricity, electromagnetic energy (RF, EMP, light, etc.), heat, flame, impact, vibration, friction, shock, blast, ionizing radiation, hostile environments, human error; precautions, safe practices, standard operating procedures; grounding, shorting, shielding; inspection techniques, system check-out trouble shooting and problem solving; safety devices, packaging and transportation; specifications, documentation, information sources, record keeping; tagging, detection and identification of clandestine explosives; reaction mechanisms, solid state reactions; chemical deactivation, disposal methods and problem, toxic effects; laboratory analytical techniques and instrumentation; surface chemistry.

Contact: E&P Affairs, The Franklin Research Center, 20th and Race Streets, Philadelphia, PA 19103 - (215) 448-1000.

MECHANICAL ENGINEERING (POWER GENERATION)

Dates: October 22-26, 1984
Place: Carson City, Nevada
Objective: Emphasizes the mechanisms behind various machinery malfunctions. Problems associated with rotating equipment used for power generation are highlighted. The seminar is designed for mechanical, maintenance, and machinery engineers who are involved in the design, acceptance testing, and operation of rotating machinery. Other topics include data for identifying problems and suggested methods of correction. The seminar also includes a lab session.

Contact: Bob Grissom, Customer Training Department, Bently Nevada Corporation, P.O. Box 157, Minden, NV 89423 - (702) 782-9315.

UNDERWATER ACOUSTICS AND SIGNAL PROCESSING

Dates: October 22-26, 1984
Place: State College, Pennsylvania
Objective: The course is designed to provide a broad, comprehensive introduction to important topics in underwater acoustics and signal processing. The primary goal is to give participants a practical understanding of fundamental concepts, along with an appreciation of current research and development activities. Included among the topics offered in this course are: an introduction to acoustic and sonar concepts, transducers and arrays, and turbulent and cavitation noise; an extensive overview of sound propagation modeling and measurement techniques; a physical description of the environment factors affecting deep and shallow water acoustics; a practical guide to sonar electronics; and a tutorial review of analog and digital signal processing techniques and active echo location developments.

Contact: Alan D. Stuart, Course Chairman, Applied Research Laboratory, The Pennsylvania State University, P.O. Box 30, State College, PA 16801 - (814) 863-4128.

MARCH

VIBRATION CONTROL

Dates: March 26-29, 1985
Place: Washington, D.C.
Objective: This vibration control course will include all aspects of vibration control except alignment and balancing. (These topics are covered in separate Institute courses.) Specific topics include active and passive isolation, damping, tuning, reduction of excitation, dynamic absorbers, and auxiliary mass dampers. The general features of commercially available isolation and damping hardware will be summarized. Application of the finite element method to predicting the response of structures will be presented; such predictions are used to minimize structural vibrations during the engineering design process. Lumped mass-spring-damper modeling will be used to describe the translational vibration behavior of packages and machines. Measurement and analysis of vibration responses of machines and structures are included in the course. The course emphasizes the practical aspects of vibration control. Appropriate case histories will be presented for both isolation and damping.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, 60514 - (312) 654-2254.

ROTOR DYNAMICS

Dates: May 6-10, 1985
Place: Syria, Virginia
Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics; fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe computers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing including turbogenerator rotors, bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

Call for Papers

NOISE-CON 85
June 3-5, 1985
Columbus, Ohio

"Computers for Noise Control" will be the theme of NOISE-CON 85, the 1985 National Conference on Noise Control Engineering. The Ohio State University in Columbus, Ohio will be the host for the June 3-5, 1985 national conference. The Ohio State Mechanical Engineering Department and the Institute of Noise Control Engineering are co-sponsoring the three-day meeting. Rajendra Singh is the General Chairman and Lynn L. Faulkner is the Technical Program Chairman.

Technical papers are being solicited in all areas of noise control engineering. Of particular interest are the following topics: personal computers for noise control, computers for laboratory use, machinery noise reduction predictions, acoustic finite element analysis and other numerical methods, prediction of filter and muffler performance, acoustic source level predictions, prediction of acoustical material performance, barrier and enclosure predictions, outdoor noise propagation, interior noise, open plan office predictions, office equipment noise, vehicle noise, active noise and vibration control, diagnostics using acoustics, positive applications of acoustic energy, measurement systems, and noise from components and systems such as gears, bearings, pumps, fans, motors, brakes, burners, furnaces and engines.

Individuals interested in submitting a paper should send a 300-word abstract to NOISE-CON 85, Department of Mechanical Engineering, The Ohio State University, 206 W. 18th Avenue, Columbus, OH 43210 - (614) 422-1910. Deadline for receipt of abstracts is October 15, 1984. Manuscripts for the Conference Proceedings are due on February 1, 1985.

JOHN C. SNOWDON VIBRATION CONTROL SEMINAR
October 22-25, 1984
Pennsylvania State University

The Pennsylvania State University will offer another one of its Vibration Control seminars on October 22-25, 1984, again under sponsorship of the Applied Research Laboratory. These seminars, which are presented by internationally known lecturers, were initiated by the late Professor C. Snowdon a decade ago and now continue under the guidance of Dr. Eric E. Ungar of Bolt Beranek and Newman, Inc. The seminars emphasize principles, general approaches and new developments, with the aim of providing participants with efficient tools for dealing with their own practical vibration problems.

For further information contact: Gretchen A. Leathers, 410 Keller Conference Center, University Park, PA 16802 - (814) 863-4563 (TWX No.: 510-670-3532).

ABSTRACTS FROM THE CURRENT LITERATURE

ABSTRACT CONTENTS

AVAILABILITY OF PUBLICATIONS ABSTRACTED

None of the publications are available at SVIC or at the Vibration Institute, except those generated by either organization.

Periodical articles, society papers, and papers presented at conferences may be obtained at the Engineering Societies Library, 345 East 47th Street, New York, NY 10017; or Library of Congress, Washington, D.C., when not available in local or company libraries.

Government reports may be purchased from National Technical Information Service, Springfield, VA 22161. They are identified at the end of bibliographic citation by an NTIS order number with prefixes such as AD, N, NTIS, PB, DE, NUREG, DOE, and ERATL.

Ph.D. dissertations are identified by a DA order number and are available from University Microfilms International, Dissertation Copies, P.O. Box 1764, Ann Arbor, MI 48108.

U.S. patents and patent applications may be ordered by patent or patent application number from Commissioner of Patents, Washington, D.C. 20231.

Chinese publications, identified by a CSTA order number, are available in Chinese or English translation from International Information Service, Ltd., P.O. Box 24683, ABD Post Office, Hong Kong.

When ordering, the pertinent order number should always be included, not the DIGEST abstract number.

A List of Periodicals Scanned is published in issues, 1, 6, and 12.

MECHANICAL SYSTEMS

ROTATING MACHINES

(Also see Nos. 1646, 1654, 1688, 1860, 1871)

84-1564

Blade Loss Transient Dynamics Analysis with Flexible Bladed Disk

V.C. Gallardo, G. Black, L. Bach, S. Cline, and A. Storace
General Electric Co., Cincinnati, OH, Rept. No. NASA-CR-168176, 269 pp (Apr 1983)
N84-13193

Key Words: Rotors, Blade loss dynamics

The transient dynamic response of a flexible bladed disk on a flexible rotor in a two rotor system is formulated by modal synthesis and a Lagrangian approach. Only the nonequilibrated one diameter flexible mode is considered for the flexible bladed disk, while the two flexible rotors are represented by their normal modes. The flexible bladed disk motion is modeled as a combination of two one diameter standing waves, and is coupled inertially and gyroscopically to the flexible rotors. Application to a two rotor model shows that a flexible bladed disk on one rotor can be driven into resonance by an unbalance in the other rotor, and at a frequency equal to the difference in the rotor speeds.

84-1565

Coupled Lateral-Torsional Vibration of Rotor System Trained by Gears (Part 1. Analysis by Transfer Matrix Method)

T. Iwatsubo, S. Arii, and R. Kawai
The Graduate School of Science and Tech., Kobe Univ., Rokko, Nada-ku, Kobe, Japan, Bull. JSME, 27 (224), pp 271-277 (Feb 1984) 15 figs, 4 tables, 5 refs

Key Words: Rotors, Gears, Coupled response, Lateral vibration, Torsional vibration, Transfer matrix method

This paper is concerned with the coupled lateral-torsional vibration of rotors trained by gears. A numerical calculation technique using the transfer matrix method is presented to obtain both free and forced vibrations. The numerical calculations are carried out in three cases: force acting on the contact line -- a function of rotation at gears; force acting on the contact line -- a function of both rotation and flexure at gears; and two rotors not coupled. The eigenvalues, eigenmodes, and responses of unbalanced mass are calculated and the results are discussed.

84-1566

Analysis of Rotor Vibration Excited by Seismic Wave

O. Matsushita, M. Takagi, and K. Kikuchi
Mech. Engrg. Res. Lab., Hitachi Ltd., 502, Kandatsu-Machi Tsuchiura-Shi, Ibaraki 300, Japan, Bull. JSME, 27 (224), pp 278-288 (Feb 1984) 18 figs, 1 table, 4 refs

Key Words: Rotors, Flexible rotors, Seismic design, Seismic waves, Clearance effects

This paper deals with rotor vibration caused by seismic wave, the influence of gyroscopic force on the response and an aseismic design method using a stopper with clearance. An analysis is presented for calculation of the response of a general flexible rotor excited by an arbitrary external force such as seismic wave. Modal techniques and step by step numerical integration are employed. The calculation method is applied to a rotor with a strong gyroscopic force.

84-1567

Nonlinear/Transient Rotor Dynamics Analysis

M.L. Adams
Case Western Reserve Univ., Cleveland, OH 44106, *Shock Vib. Dig.*, 16 (3), pp 3-6 (Mar 1984) 2 figs, 20 refs

Key Words: Rotors, Transient response, Nonlinear response, Reviews

This review article presents an update of work since 1980. Because this topic -- nonlinear/transient rotor dynamics -- is a specialty within the specialty of rotor dynamics, the number of investigators concentrating on it is not large. However, the significance of recent work to various types of rotating machinery is high.

84-1568

Dynamic In-Plane Response at the Centre of a Rotating Elastic Disc Due to Oscillatory In-Plane Forces at the Rim

R.J. Pinnington

Southampton Univ., UK, Rept. No. ISVR-TR-121, 59 pp (Oct 1982)
N84-13613

Key Words: Disks, Rotating structures

The vibration response at the center of a rotating disc which is subjected to in-plane, normal and tangential forces at the rim is analyzed. Such a disc will behave as a rigid body at low frequencies, with the acceleration at the center in phase with force at the rim. However, to analyze the response at higher frequencies it is necessary to consider wave motion within the disc. The vibration analysis of the disc involves two uncoupled wave equations expressed in plane polar co-ordinates. The general solution to each of these equations is a summation of orthogonal modes.

84-1569

Analysis of Shaft Alignment Taking Oil Film Characteristics of Stern Tube Bearing into Consideration (Part 1, Theoretical Analysis)

J. Mitsui and Y. Akutsu
Tamano Lab., Mitsui Engrg. & Shipbuilding Co., Ltd. 1-1, Tama 3-chome, Tamano, Okayama, Japan, Bull. JSME, 27 (224), pp 317-324 (Feb 1984) 19 figs, 2 tables, 3 refs

Key Words: Shafts, Alignment, Marine propellers, Oil-film bearings, Fluid-film bearings

To achieve energy savings, ships are now being designed with larger propellers operating at lower speed. Such designs impose a heavier load on the stern tube bearing. Shaft alignment calculations are made taking into consideration oil film characteristics of the stern tube bearing. The oil film characteristics are analyzed applying the finite width hydrodynamic theory to the curved shaft in the stern tube bearing. This theoretical analysis makes it possible to elucicate the oil film characteristics. The optimum width-diameter ratio of the stern tube bearing at lower speed is also obtained by this analysis.

84-1570

Torsional Vibration of Crankshafts in Reciprocating Machines

D.K. Rao
Wright-Patterson Air Force Base, OH 45433, Shock Vib. Dig., 16 (2), pp 15-23 (Feb 1984) 103 refs

Key Words: Shafts, Crankshafts, Reciprocating engines, Torsional vibration, Reviews

Crankshafts and connected shafting in reciprocating engine-driven systems such as ship propulsion drives, air compressors, diesel generator sets, and automobiles can fail if excessive torsional vibratory stresses are developed due to a torsional mismatch between driving and driven machinery. This paper reviews current literature dealing with determination of torsional natural frequencies and vibratory stresses in reciprocating machinery shafting.

84-1571

Optimum Design of Rotating Machines with Overhung Weight, Part 1: Formulation of Optimum Problems

A. Sueoka, H. Tamura, Y. Tsuda, and H. Yamasaki
Kyushu Univ., Higashi-ku, Fukuoka-shi, Japan, Bull. JSME, 27 (223), pp 79-86 (Jan 1984) 8 figs, 12 refs

Key Words: Optimum design, Shafts

Regarding rotating machines with overhung weight as a system with one shaft and one rigid body, the extreme value problems of the static natural frequencies, forward and backward critical speeds under constant volume of the shaft are formulated by using the matrix method by which the spring constants of the axial symmetric structure are directly calculated. In this case, the shaft of a rotating machine consists of uniform beams which are connected in series with one another. Besides the length, inside and outside diameters of every beam that is an element of the shaft, the distance between shaft/rigid body connection point and center of gravity of the rigid body is used as a design variable.

84-1572

Acoustic Ranging Technique with Application to Assessment of Low-Frequency Acoustic Noise of Wind Turbines

R. Hemphill
Solar Energy Res. Inst., Golden, CO, (Pres. at the Wind/Solar Energy Conf., Kansas City, MO, Apr 25, 1983), Rept. No. SERI/TP-215-1954, CONF-830432-3, 12 pp (May 1983)
DE83009406

Key Words: Wind turbines, Noise generation, Low frequencies

Impulsive low-frequency noise from wind turbines can cause annoyance particularly when a residential structure is involved. Such noise is typically generated in some spatially restricted region of a turbine rotor swept area. Low-frequency impulsive noise of the MOD-1 turbine was generated when the rotor blades passed downwind of the tower legs encountering the complex unsteady flows there. An acoustic ranging technique that aids assessment of the degree of concentration of acoustic generation within the turbine swept area and which determines the time-average spatial source region of such concentration is described. Practical applications and limitations of the process are discussed.

RECIPROCATING MACHINES

(Also see Nos. 1570)

84-1573

Basic Research on Vibration and Noise of Internal Combustion Engine (1st Report, Vibration Analysis of the Piston-Crank System I)

M. Nagaike and A. Nagamatsu
Tokyo Inst. of Tech., 12-1, Ohokayama 2-chome, Meguro-ku, Tokyo, 152, Japan, Bull. JSME, 27 (224), pp 289-294 (Feb 1984) 15 figs, 1 table, 4 refs

Key Words: Internal combustion engines, Substructuring methods, Building block approach, Natural frequencies, Mode shapes, Transfer functions

A vibration analysis of the piston-crank system of an internal combustion engine is made. The system is composed of three substructures: a piston, a connecting rod, and a combined system of a crankshaft and a flywheel. The transfer functions of each substructure are obtained by the reduced impedance method. The transfer functions of a bearing are obtained experimentally by the harmonic exciting test. Natural frequencies, natural modes and transfer functions of the whole body are determined with the transfer functions of each substructure and bearing parts by the building block approach.

84-1574

Dynamic Analysis of the Fluidyne

C.D. West
Oak Ridge National Lab., TN, Rept. No. CONF-830812-49, 27 pp (1983) (18th Intersociety Energy Conversion Engrg. Conf., Orlando, FL, Aug 21, 1983) DE83017283

Key Words: Internal combustion engines

The dynamic behavior of the liquid-piston Stirling engine is analyzed using the vector or phasor method of representing the motions of coupled systems. The result, for the first time, is a simple physical explanation of the feedback mechanism most frequently employed in these machines. In addition, the method leads to an easy derivation of certain results already known from experiment or from more complex analyses.

84-1575

Forced Oscillation Experiments in Supercritical Diffuser Flows

M. Sajben, T.J. Bogar, and J.C. Kroutil
McDonnell Douglas Corp., St. Louis, MO, AIAA J., 22 (4), pp 465-474 (Apr 1984) 16 figs, 1 table, 17 refs

Key Words: Jet engines, Combustion excitation, Vibration response

Low-frequency oscillations induced in ramjet inlets by combustion instabilities were simulated by mechanically modulating the exit area of a two-dimensional, supercritical diffuser at frequencies up to 330 Hz. Boundary layers were attached below a terminal shock Mach number of 1.27, and shock-induced separation occurred above this value up to the experimental limit of 1.35. Shock position histories were obtained and streamwise distributions of static/total dynamic pressures were determined both on the wall and within the flow for various shock strengths and frequencies. Excitation at the natural frequencies of the shock motion produced no obvious resonance effects.

METAL WORKING AND FORMING

84-1576

Development and Application of Multiple Input Models for Structural Noise Source Identification of Forge Hammers. Part I: Development

M.W. Trethewey and H.A. Evensen
Pennsylvania State Univ., University Park, PA 16802, J. Acoust. Soc. Amer., 75 (4), pp 1092-1098 (Apr 1984) 10 figs, 32 refs

Key Words: Forging machinery, Noise source identification, Multipoint excitation technique

The application of multiple input models to analyze structurally generated noise from a forge hammer is discussed. This article is intended to present the rationale for application and analysis of multiple input models for noise source identification. The development of the empirical models is reviewed and investigated to show how the terms in the model can be interpreted to mathematically simulate the selective wrapping approach to source identification. The interaction of the structural excitation forces and radiated structural noise is examined for a four-piece forge hammer and provides an indication of the characteristic measurements needed to develop the multiple input model that is representative of the hammer's sound radiation. The transducer requirements for application to forge hammers are examined through experiments performed on a laboratory test structure and a forge hammer column. The results indicate that a single, well-placed transducer may be sufficient to characterize the sound radiation from a monolithic element.

84-1577

Development and Application of Multiple-Input Models for Structural Noise Source Identification of Forge Hammers. Part II -- Application

M.W. Trethewey and H.A. Evensen

Pennsylvania State Univ., University Park, PA 16802, J. Acoust. Soc. Amer., 75 (4), pp 1099-1104 (Apr 1984) 6 figs, 3 tables, 3 refs

Key Words: Forging machinery, Noise source identification, Multipoint excitation technique

This article analyzes the application of the multiple-input modeling technique to the structural noise source identification of a Chambersburg no. 8 die forger. A comparison of three-, five-, and seven-input models applied to the forge hammer under production conditions indicates that as few as five transducers would suffice to characterize the sound contributions of the five structural elements. Analysis of these models indicates that the ram is the dominant source of sound energy, the columns are secondary sources, and the yoke and anvil are minor source when detected through a microphone at the operator's position. The analysis also shows that the coupling between the hammer structural elements is sufficient to render conventional wrapping identification methods unreliable for analyzing hammer noise.

84-1578

Machine Tool Modifications with Tuned Dampers

P.J. Riehle and D. Brown

Anatrol Corp., Cincinnati, OH, S/V, Sound Vib., 18 (1), pp 34-39 (Jan 1984) 14 figs, 8 refs

Key Words: Machine tools, Chatter, Dynamic vibration absorption (equipment), Viscoelastic damping

Machine tool vibration problems associated with chatter and how these problems can be corrected with the application of tuned dampers are discussed. The fundamentals of self-excited and forced machine tool chatter and techniques for reducing chatter are briefly described. The process of designing tuned dampers for structural modifications is reviewed with special emphasis placed on the selection of viscoelastic damping materials. A case study involving a machine tool chatter problem and its solution with a tuned damper is described in detail.

84-1579

On-Line Identification and Control of Machining Chatter in Turning through Dynamic Data System Methodology

Shing-Yuan Tsai

Ph.D. Thesis, Univ. of Wisconsin-Madison, 286 pp (1983)

DA8323406

Key Words: Chatter, Machine tools, Vibration control

The time-varying stability of the machining process necessitates a technique of on-line chatter identification and control. In a six-stage study, such a technique was sought. The theoretical derivation and developed strategy presented in this study have provided a solid basis for developing a chatter free lathe.

STRUCTURAL SYSTEMS

BRIDGES

84-1580

Experimental and Analytical Evaluation of Causes of Cracking in Precast Panel Highway Bridges

F.E. Fagundo and C.O. Hays, Jr.

Univ. of Florida, Gainesville, FL, ISA Trans., 23 (1), pp 1-9 (1984) 10 figs, 6 refs

Key Words: Bridges, Panels, Precast concrete, Crack propagation, Moving loads

Time and economic factors favor composite precast deck bridges over conventional cast-in-place decks. Although both systems have been used successfully for many years, the precast system exhibits more regular cracking patterns than the cast-in-place system. Based on field measurements of deflection patterns, both under static and dynamic moving vehicle loads, laboratory testing on specimens subjected to cyclic loads, sample cores obtained from the structure, and finite element modeling, the causes of cracking have been identified. Differential creep and shrinkage and, where applicable, the lack of positive bearing of the precast panels over the girders all contribute in different proportions to the cracking. Preliminary evaluation of the effects of cracking, suggestions on how to improve the performance of the deck system, and description of continuing work on laboratory testing is presented. A rapid automatic data acquisition system is described for obtaining field and laboratory data.

84-1581

Bridge Pile Damage upon Vessel Impact

K.N. Derucher

Stevens Inst. of Tech., Hoboken, NJ 07030, Computers Struc., 18 (5), pp 931-935 (1984) 8 figs, 4 refs

Key Words: Pile structures, Bridges, Ships, Collision research (ships)

Many piers of bridges that span navigable waters are increasingly subjected to vessel impact. Many of these bridge piers are concrete and are constructed such that the piling system and the bridge pier are one. Depending upon the size and the material of the pile and upon vessel impact there may be a failure within the pile itself or at the pile-pier intersection. If the impact is great enough, the failure or fracture may be a complete one, and the pier moves horizontally and/or vertically. Thus, failure of the bridge may result while the pier is still intact. A new bridge may be built or rehabilitated using the existing pier which may now be inadequate. In many cases the amount of piling failure is difficult to assess. A procedure has been developed to determine the amount of pier movement (failure of the piles) that might occur. The procedure uses a modification of two existing computer programs (a lateral pile program and a pile group program).

84-1582

Fatigue Resistance of Riveted Steel Truss Bridge Members and Joints

Chun Kyung Seong

Ph.D. Thesis, Lehigh Univ., 268 pp (1983)
DA8329476

Key Words: Bridges, Structural members, Joints (junctions), Riveted joints, Fatigue life

The fatigue resistance of old riveted truss bridge members and joints is investigated. Clamping forces in rivets and friction between interfacing plates are considered not dependable and ignored. The components of riveted details are subsequently resolved into plane stress plates. Emphasis is placed on developing an analytical procedure for estimating fatigue crack propagation life of riveted truss details. The analysis of member stresses is conducted by finite element modeling of a bridge span as a three dimensional space frame. Redistribution of stresses in truss bridge members when one develops a crack is examined by assuming the reduction of cross section occurs throughout the member length. By using singular isoparametric plane stress elements, the fracture mechanics stress intensity factor for cracks emanating from rivet holes is evaluated through a virtual crack extension method. Two types of details are studied: riveted built-up truss members with no transfer of load between component plates and riveted truss joints where rivets transfer loads by bearing.

BUILDINGS

84-1583

The Effect of the Angle of Incidence on Residential Acoustical Insulation

F.L. Hall and N. Bechrakis

McMaster Univ., Hamilton, Ontario, Canada L8S 4L7, Noise Control Engrg. J., 22 (2), pp 42-47 (Mar/Apr 1984) 1 table, 15 refs

Key Words: Buildings, Noise reduction, Airports

The effectiveness of acoustical insulation in residential housing near airports may vary during an aircraft flyover, depending on the relative location of the flight paths and the housing, because the angle of incidence of sound waves affects transmission loss. Alternatively, the number of reflected paths in normal residential areas may be so great as to override any such effect. This paper tests these two possibilities using field data collected for 20 rooms. The results show that the mean value of the decrease in insulation during an aircraft flyover is close to 5 dB. For those cases where the aircraft passes directly over the house, the lowest insulation values occur at the time when the outdoor sound due to the aircraft is at its highest level.

84-1584

Cladding Influence on Dynamics Response of Tall Buildings

H. Palsson, B.J. Goodno, J.I. Craig, and K.M. Will
Swiss Fed. Inst. for Reactor Res., Wuerenlingen, Switzerland, Earthquake Engrg. Struc. Dynam., 12 (2), pp 215-228 (Mar/Apr 1984) 11 figs, 7 tables, 19 refs

Key Words: Buildings, Multistory buildings, Cladding, Seismic design

Precast concrete panels form attractive facades for steel frame buildings and are generally regarded as nonstructural by structural engineers. However, panels have been found to add lateral stiffness until their capacity or that of their connections is exceeded. Consequently, the computed dynamic response based on a model of the structural framing alone may be quite different from that experienced by the actual structure. As a case study, the influence of precast concrete panels on lateral and torsional stiffness of a 25-story building is investigated. The effect of cladding on dynamic properties and linear seismic response is explored by varying panel stiffness.

84-1585

An Alternative Approach to the Random Response of Bilinear Hysteretic Systems

K. Asano and W.D. Iwan
Kansai Univ., Osaka, Japan, Earthquake Engrg. Struc. Dynam., 12 (2), pp 229-236 (Mar/Apr 1984) 6 figs, 11 refs

Key Words: Buildings, Hysteretic damping, Random excitation, Equivalent linearization method

An analytical representation of the bilinear hysteretic characteristic is presented. Using this representation, the response of a single-degree-of-freedom bilinear hysteretic system subjected to nonstationary random excitation is examined by equivalent linearization. An ordinary differential equation is derived for the covariance matrix of the response. Numerical examples are presented and the accuracy of the approach is demonstrated. Extension of the approach to a wider class of hysteretic systems is discussed.

84-1586

Comparison of Outdoor Microphone Locations for Measuring Sound Insulation of Building Facades

F.L. Hall and M.J. Papakyriakou
McMaster Univ., Hamilton, Ontario, Canada K1A OR6, J. Sound Vib., 92 (4), pp 559-567 (Feb 22, 1984) 1 fig, 4 tables, 5 refs

Key Words: Buildings, Acoustic insulation, Measurement techniques

Measurement of the acoustical insulation of building facades requires simultaneous measurement of sound pressure levels indoors and outdoors, but there is still some question as to the best location for the outdoor microphone. This paper reports the differences between sound pressure levels at 2 m from a facade and at its surface, for a series of measurements at 33 different houses.

84-1587

Soil-Structure Interaction Effects on the Steady-State Response of Torsionally Coupled Buildings

T.G. Tsicnias and G.L. Hutchinson
Univ. of London King's College, London, UK, Earthquake Engrg. Struc. Dynam., 12 (2), pp 237-262 (Mar/Apr 1984) 16 figs, 2 tables, 21 refs

Key Words: Buildings, Interaction: soil-structure, Seismic excitation

The effect of the foundation flexibility on the coupled lateral-torsional response of single story buildings excited by translational ground motion is investigated. The eccentricity between the center of mass and the center of resistance is considered to be the only cause of coupling of the lateral and torsional response of the building. The study is confined to the steady-state response of rigidly supported and flexibly supported torsionally coupled buildings subjected to harmonic free-field ground displacement perpendicular to the direction of the eccentricity. In the case of the flexibly supported building the foundation medium is assumed to be an elastic homogeneous isotropic halfspace. The effect of the controlling parameters on lateral-torsional coupling is investigated.

84-1588

Hazardous Buildings: Aspects of the Los Angeles Earthquake Problem

D.M. Lee and R. Shepherd
Univ. of Chicago, Chicago, IL, Earthquake Engrg.

Struc. Dynam., 12 (2), pp 149-167 (Mar/Apr 1984) 24 figs, 6 refs

Key Words: Buildings, Seismic design

In recognition of the life-threatening dangers posed by many thousands of buildings completed prior to the requirement for provision of any specific earthquake resistance, in 1981 the city of Los Angeles adopted a seismic safety ordinance requiring the upgrading of these buildings to predetermined engineering standards. Various methods of modifying such structures, which are characteristically of unreinforced multi-story masonry bearing wall configuration with interior wood framing, are summarized in this paper. In addition to presenting typical structural details, some of the socio-economic and financial aspects of the earthquake hazard mitigation program are discussed.

84-1589

Dynamic Response of Buildings to Ground Rotational Motion

A.M. Awad and J.L. Humar

Faculty of Engrg., Univ. of Alexandria, Alexandria, Egypt, Can. J. Civil Engrg., 11 (1), pp 48-56 (Mar 1984) 7 figs, 13 refs

Key Words: Buildings, Torsional response, Seismic excitation

Torsional motion in a building subjected to earthquake force is often attributed to an eccentricity between the centers of mass and resistance of the building. However, a more direct cause of torsional response is the presence of a rotational component in the earthquake motion. The effect of such a rotational motion on the response of both a symmetric and an unsymmetric single story building model is studied. It is shown that the rotational component of excitation may have a very significant effect on the response, and that this effect may at times be more pronounced than the effect of torsion resulting from translational motion combined with plan eccentricity.

84-1590

The Optimum Design of a Base Isolation System with Frictional Elements

M.C. Constantinou and I.G. Tadjbakhsh

Rensselaer Polytechnic Inst., Troy, NY, Earthquake Engrg. Struc. Dynam., 12 (2), pp 203-214 (Mar/Apr 1984) 5 figs, 6 tables, 15 refs

Key Words: Buildings, Multistory buildings, Seismic design, Base isolation

A linear multistory structure with a seismic base isolation system consisting of rubber bearings and frictional elements is considered. The nonlinear equations of motion are derived for the first mode vibration and the stochastic response to a white noise ground acceleration is determined. Based on this response, suitable objective functions are defined and the optimum design of the isolation system is performed. It is shown that a small amount of friction increases the effectiveness of the system compared with the same system but without frictional elements.

TOWERS

84-1591

Dynamics of a Freestanding Steel Lighting Tower

K.C.S. Kwok, G.J. Hancock, P.A. Bailey, and P.T. Haylen

School of Civil and Mining Engrg., Sydney Univ., Australia, Rept. No. R-450, 30 pp (June 1983) PB84-137934

Key Words: Towers, Steel, Natural frequencies, Mode shapes

Results of full scale measurements of the dynamic characteristics of a steel lighting tower are presented. The first three natural frequencies of vibration were found to be 0.50 Hz, 2.40 Hz and 4.84 Hz respectively. The corresponding mode shapes were also determined. These results are compared with those obtained from a plane rigid frame dynamic analysis computer program and found to be in good agreement.

FOUNDATIONS

84-1592

Earthquake Response of Structures with Partial Uplift on Winkler Foundation

Chik-Sing Yim and A.K. Chopra

Univ. of California, Berkeley, CA, Earthquake Engrg. Struc. Dynam., 12 (2), pp 263-281 (Mar/Apr 1984) 12 figs, 12 refs

Key Words: Winkler foundations, Foundations, Seismic response

The effects of transient foundation uplift on the earthquake response of flexible structures are investigated. The structural idealization chosen in this study is relatively simple but it incorporates the most important features of foundation uplift. In its fixed base condition the structure itself is idealized as a single-degree-of-freedom system attached to a rigid foundation mat which is flexibly supported. The flexibility and damping of the supporting soil are represented by a Winkler foundation with spring-damper elements distributed over the entire width of the foundation. Based on the response spectra presented for several sets of system parameters, the effects of foundation-mat uplift on the maximum response of structures are identified. The influence of earthquake intensity, structural slenderness ratio, ratio of foundation mass to structural mass, foundation flexibility and p-δ effects on the response of uplifting structures is also investigated.

UNDERGROUND STRUCTURES

84-1593

Dynamic Response of Twin Circular Tunnels Due to Incident SH-Waves

T. Balendra, D.P. Thambiratnam, Chan Ghee Koh, and Seng-Lip Lee

Natl. Univ. of Singapore, Singapore, Earthquake Engrg. Struc. Dynam., 12 (2), pp 181-201 (Mar/Apr 1984) 12 figs, 2 tables, 10 refs

Key Words: Tunnels, Underground structures, Wave reflection

The steady-state solution for two parallel underground tunnels of circular cross-section subjected to incident plane harmonic SH-waves is obtained in closed form, by using the method of wave function expansion. The image technique is employed to account for the reflection of waves at the ground surface. Numerical studies are carried out to determine the influence of spacing between the tunnels on the shear stresses in concrete and steel linings.

84-1594

R/C Structures under Impulsive Loading

J. Ghaboussi, W.A. Millavec, and J. Isenberg

Univ. of Illinois, Urbana, IL, ASCE J. Struc. Engrg., 110 (3), pp 505-522 (Mar 1984) 15 figs, 1 table, 14 refs

Key Words: Underground structures, Reinforced concrete, Aerial explosions, Ground shock, Explosion effects

A finite element method is presented to analyze the effects of airblast-induced ground shock on shallow-buried, flat-roofed, reinforced concrete structures. A finite element based on Timoshenko beam theory is adopted. Material properties are defined in terms of nonlinear stress-strain relations in each of several layers through the thickness of the element. Elastic, ideally-plastic constitutive properties for plain concrete are cast in terms of shear-stress/normal-stress variables. Elastic, strain-hardening constitutive properties are assumed for steel. Dynamic explicit and implicit and static solution algorithms are available.

POWER PLANTS

(Also see Nos. 1753, 1757)

84-1595

Suitability of Synthesized Waveforms for Seismic Qualification of Equipment

D.D. Kana and D.J. Pomerening

Southwest Res. Inst., San Antonio, TX 78284, J. Pressure Vessel Tech., Trans. ASME, 106 (1), pp 63-68 (Feb 1984) 15 figs, 14 refs

Key Words: Nuclear power plants, Equipment response, Seismic response, Qualification tests

Qualification of nuclear plant equipment and components can be performed by analysis, test, or a combination of both. It is often required to synthesize artificial time histories which represent earthquake excitation at either ground level, or some elevated level of a structure. A set of parameters appropriate for the synthesis of acceleration time histories is developed. The parameters are based on a study of six typical earthquake accelerograms, and include general characteristics of the motion, a definition of strong ground motion, frequency content, stationarity, coherence between orthogonal components, and amplitude probability density. It is concluded that the strong ground motion can be approximated by a stationary Gaussian random process, whose frequency content depends on the ground or elevated position of concern.

OFF-SHORE STRUCTURES

84-1596

Hydrodynamic Forces on Flexible Offshore Structures

E.J. Laya, J.J. Connor, and S.S. Sunder

INTEVEP, S.A., Caracas, Venezuela, ASCE J. Engrg. Mech., 110 (3), pp 433-448 (Mar 1984) 7 figs, 1 table, 25 refs

Key Words: Off-shore structures, Interaction: structure-fluid, Hydrodynamic excitation

The extension of Morison's equation to allow for structural motion in predicting the hydrodynamic force on offshore steel jacket platforms may be based on two different hypotheses: the relative velocity model which replaces the fluid velocity by the relative velocity between the fluid and the structure; and the independent flow fields model which considers the flow to be a superposition of two unrelated flows, one due to the wave-current action on a rigid cylinder, and the other due to the structural motion in still water. An iterative computational procedure that combines time domain and frequency domain analysis techniques is developed to solve the nonlinear governing equations for both models. Comparison studies are carried out for seastates ranging from the drag dominant through the inertia dominant regimes.

VEHICLE SYSTEMS

GROUND VEHICLES

(Also see Nos. 1637, 1638, 1639, 1731)

84-1597

A Search for Priorities in Crash Protection

A.C. Malliaris and J.Hedlund

Natl. Highway Traffic Safety Admn., SAE Paper No. 820242 (SP-513)

Key Words: Collision research (automotive)

This paper presents the methodology and results of an analysis of the available information on motor vehicle safety which could be used to provide a basis for establishing priorities for future Government and private sector efforts directed at enhanced crash protection. This study uses the National Highway Traffic Safety Administration's automated data files on personal injury as the baseline information on injuries sustained by restrained and unrestrained occupants of all types of vehicles, and by pedestrians and cyclists. This information is analyzed according to the magnitude of harm sustained, the potential for reduction in harm, and the relative adequacy of data and methods available for the exploration of solutions.

84-1598

Light Vehicle Frontal Impact Protection

D.S. Cohen, E. Jettner, and W.E. Smith

Natl. Highway Traffic Safety Admn., SAE Paper No. 820243 (SP513)

Key Words: Collision research (automotive)

This paper addresses the protection of occupants in light vehicles. It presents data and techniques for identifying and measuring potential crashworthiness improvements that would mitigate injuries to occupants striking frontal interior components such as the steering wheel, instrument panel and windshield. The focus of this paper is on the unrestrained occupant. Information is presented on the magnitude and types of injuries received from frontal interior components and on how the performance of these components and the vehicle structure affect the resultant injuries.

84-1599

The Role of the Side of the Motor Vehicle in Crash Protection

A. Burgett and W. Brubaker

Natl. Highway Traffic Safety Admn., SAE Paper No. 820245 (SP513)

Key Words: Collision research (automotive)

Collision related injuries associated with the side of passenger vehicles are a major part of the price of motor vehicle accidents. Three methods for evaluating the crash-related safety characteristics of the sides of motor vehicles are examined. One method uses a full-scale crash test for the evaluation of performance. A second method uses subsystem, or component, tests and the third method relies on analytical procedures for the evaluation.

84-1600

Static and Dynamic Tests of Wheelchair Restraints for Use in Public Service Vehicles

S.P.F. Petty and A.G. Chatfield

Transport and Road Res. Lab., Crowthorne, UK, Rept. No. TRRL/LR-1087, 15 pp (1983)

PB84-142561

Key Words: Safety restraint systems, Wheelchairs, Testing techniques, Dynamic tests

Four types of basic wheelchair restraint design were tested. These were: a webbing belt system adapted from a cargo restraint design; strapping the wheelchair frame to steel rails bolted onto the floor and/or walls of the PSV; a clamp on one side of the wheelchair and a separate webbing belt on the other side, anchored to the opposite corner of the wheelchair frame and mounted in the floor in an extruded aluminum alloy rail; a vertical clamp on each side of the wheelchair frame attached to the floor; and an adjustable 'A' frame placed at the back of the wheelchair in sockets in the vehicle floor and roof. The static tests were carried out on a frame which was used to load the restraints in the forward, sideways and rearward modes, with the wheel castors set for forward wheelchair motion. The dynamic tests were carried out on an impact sled, with a dummy seated in the chair.

84-1601

Wheelchair Restraint Systems, Dynamic Test Results and the Development of Standards

E. Red, K. Hale, M. McDermott, and B. Mooring
Mech. Engrg. Dept., Texas A&M Univ., SAE Paper No. 821161 (P-113)

Key Words: Automobiles, Safety restraint systems, Impact tests

Wheelchair restraint devices/systems have been developed to restrain the wheelchair and provide the wheelchair occupant some measure of protection in normal and abnormal (crash) driving situations. The proliferations of these devices, some of which afford minimal restraint to the wheelchair occupant, led to the development of a program to test and evaluate representative restraint devices currently being marketed. This paper describes the progress that has been made in this program to-date. Included are the descriptions of the test facility, photographs of some of the actual impact tests and the description of a new restraint system that is under development.

84-1602

The Performance of Passenger Cars on Uneven Roads (Fahrverhalten von Personenkraftwagen auf unebener Strasse)

M. Mitschke
Institut f. Fahrzeugtechnik, Technische Universitat Hans-Sommer-Strasse 4, 3300 Braunschweig, Automobiltech. Z., 85 (11), pp 695-698 (Nov 1983) 10 figs, 3 refs
(In German)

Key Words: Automobiles, Surface roughness, Tires

This article reports on findings from experiments on tire-testing stands, driving on a circular track. The findings from the tire experiments show that the curve of lateral force due to slip angle flattens out as dynamic wheel load increases. According to experiments done on a circular track, the tendency to over/understeer changes on uneven roads. Theoretical observations suggested that the tendency to over/understeer is hardly changed when fluctuations in the wheel load acting on front and rear wheels are nearly the same.

84-1603

Modelling of the Fatigue Damage Processes of Bus Frames

P. Michelberger, J. Ginsztler, A. Keresztes, and P. Varlaki
The Technical Univ., Budapest, H-1502, BP pf 91, Hungary, Intl. J. Fatigue, 6 (2), pp 107-112 (Apr 1984) 12 figs, 6 refs

Key Words: Fatigue life, Buses

A procedure for calculating the stress level intersection numbers for a given model of a bus frame operating in a steady-state mode is presented. Comparison of the calculated results with previous experimental data shows that the proposed method of computation gives an accurate approximation of physical reality. Knowledge of the stress level intersection numbers permits designers to establish which vehicle components are prone to fatigue failure.

84-1604

Acoustically Conspicuous Truck Trailers Individual Noise-Generating Problem Areas – Part 2 (Auffälige Nutzfahrzeug-Anhänger Einzelprobleme ihrer Geräuschentwicklung – Teil 2)

S. Jäkel
Automobiltech. Z., 85 (10), pp 625-631 (Oct 1983) 15 figs
(In German)

Key Words: Trucks, Trailers, Articulated vehicles, Noise generation

Part 1 of this study classifies the noise conditions typical of acoustically conspicuous truck trailers in road traffic including the noise caused by the striking, rattling or squeaking of trailer parts. Part 2 covers some of the measurements and findings applicable to unloaded trailers with leaf springs.

84-1605

Steady and Transient Turning of Tractor-Semitrailer and Truck-Trailer Combinations: A Linear Analysis (Stationär- und Übergangsverhalten von Sattel- und Lastzügen bei der Kreisfahrt: Lineare Berechnungen)

F. Vlk

Technical Institute of Bern, Obráncú míru 65, CS-602 00 Brno, Czechoslovakia, Vehicle Syst. Dynam., 12 (6), pp 331-350 (Dec 1983) 14 figs, 2 tables, 23 refs

(In German)

Key Words: Articulated vehicles, Ride dynamics

A simplified analysis is made of the yaw stability and control of two types of commercial vehicle combinations (tractor-semitrailer, truck-trailer) at a constant forward velocity during steady and transient turning. The combined vehicle is treated as a linear dynamic system. The steer angle at the front wheels of the tractor (or truck) and the steady-state responses of the road vehicle train (yaw rate, articulation angles and sideslip angle) are calculated. Exploratory calculations are performed to determine the influence of the cornering stiffness of the tires for the two types of the vehicle combinations upon the steady-state responses.

84-1606

Basic Analytical Results for Lateral Stability of Car/Trailer Systems

J.C. Huston and D.B. Johnson

Iowa State Univ., Ames, IA, SAE Paper No. 820136 (SP-509)

Key Words: Trucks, Articulated vehicles, Lateral response

Basic analytical results for car/trailer lateral stability are developed. These results are validated by comparing critical speeds predicted by the new analytical solution with those obtained numerically using a standard eigenvalue technique. General observations based upon the analytical results are presented.

84-1607

Validation of Computer Prediction of Train Passby Noise-Exposure Levels

J.M. Hague III

Buffalo, NY, ASME Paper No. 83-WA/NCA-6

Key Words: Railroad trains, Noise prediction

The contribution of line-haul rail traffic to community noise levels can be quantified by trains' single-event noise exposure levels, Senel, at noise-sensitive wayside locations such as residences. The cumulative effect of a day's operations can be assessed, under ICC guidelines, by the change in day-night noise level, L_{dn}, associated with proposed changes in operations.

84-1608

Vibration Modes of a 70-Ton Boxcar

C.L. Orth and G. Kachadourian

Fed. Railroad Admn., Washington, DC 20590, J. Engrg. Indus., Trans. ASME, 106 (1), pp 21-27 (Feb 1984) 18 figs, 4 tables, 4 refs

Key Words: Railroad cars, Freight cars, Experimental modal analysis, Mode shapes

Vibration tests were performed on a 70-t boxcar both empty and fully loaded, with two packaging configurations. Nine vibration modes were identified: first roll, second roll, yaw, bounce, pitch, body torsion, body bending, and two lading modes. The effect of friction snubbing, gross weight, and amplitude of motion input at the rails was determined. Test results presented are a summary of modal frequencies, the deflections associated with each mode and the range of frequency variation.

84-1609

Stiffness and Friction Force Measurements on a Freight Car Truck from Quasi-Static Tests

G. Kachadourian, C.L. Orth, and D.W. Inskeep

The MITRE Corp., J. Engrg. Indus., Trans. ASME, 106 (1), pp 16-20 (Feb 1984) 15 figs

Key Words: Vibration tests, Railroad cars, Freight cars, Stiffness coefficients, Friction excitation, Experimental data

A conventional three-piece truck with load sensitive friction snubbing was tested as a complete assembly with its wheels resting on a fixed section of rail and with loads applied through a fixture that duplicated the body bolster at the truck bolster interface. The purpose of the testing was to determine the stiffness and friction forces of the truck under vertical, lateral, and roll moment loading conditions. Loads were varied to cover a range of car gross weight conditions.

84-1610

Optimal Simple Span Lengths for Flexible Guideways

L. Minnetyan

Clarkson College of Tech., Potsdam, NY 13676, ASCE J. Struc. Engrg., 110 (1), pp 138-153 (Jan 1984) 8 figs, 2 tables, 7 refs

Key Words: Interaction: vehicle-guideway

In the design of elevated vehicle/guideway systems several parameters play important roles in the dynamic performance. The vehicle inertial and suspension properties, guideway mass per unit length, span length, structural damping characteristics and surface finish tolerances are important factors. The two most important dynamic phenomena which require accommodation in the system design are vehicle suspension resonance and guideway beam resonance. A detailed dynamic assessment of the optimum simply supported guideway span length is presented. The effects of all parameters to the system performance are examined and critical parametric combinations are identified for a practical design example of a vehicle/guideway system.

84-1611

Vehicle-Structure Interactions in Bridge Dynamics

E.C. Ting and M. Yener

Purdue Univ., West Lafayette, IN 47907, Shock Vib. Dig., 15 (12), pp 3-9 (Dec 1983) 41 refs

Key Words: Interaction: vehicle-structure, Interaction: vehicle-guideway, Bridges, Reviews

A great amount of literature exists on dynamic interaction problems concerning guideways and moving vehicles. Because of the mathematical difficulties introduced by the coupling terms in the behavioral governing differential equation, the transverse inertia effect of a moving vehicle is often neglected. With the improved availability of advanced computer methods and facilities, it has become possible to take into account the kinematics of the interaction problem. In this article recent developments in analytical and numerical approaches for solving vehicle-guideway interaction problems are discussed; related recent literature is cited. In addition, recently relevant experimental developments are presented.

84-1612

Coupled Lateral Vibrations Between Rail and Railway Vehicle's Wheels. Part 1: Equations of Motion of Rail and Its Characteristics

A. Sueoka, T. Ayabe, and H. Tamura

Kyushu Univ., Hakozaki, Higashi-ku, Fukuoka-shi, Japan, Bull. JSME, 26 (222), pp 2193-2199 (Dec 1983) 8 figs, 12 refs

Key Words: Interaction: rail-wheel, Coupled response, Lateral vibration

A study on the coupled lateral vibration between the rail and railway vehicle's wheels is presented. The rail is modeled as an infinitely long beam on an elastic foundation with two springs with respect to lateral deflection and torsion. The equations of motion describing a coupled vibration between lateral deflection and torsion of rail are introduced. The problems of lateral and vertical steady state vibration of rails are formulated assuming that the contact point between a wheel and a rail moves at constant speed. The mechanical impedance and displacement function are obtained in order to clarify the dynamic characteristics of the rail.

SHIPS

84-1613

Two-Dimensional Unsteady Planing Surface

M. Bessho and M. Komatsu

Natl. Defense Academy, Yokosuka, Japan, J. Ship Res., 28 (1), pp 18-28 (Mar 1984) 5 figs, 22 refs

Key Words: Boats, Airfoils, Hydrodynamic excitation

The two-dimensional unsteady problem of a flat planing surface is analyzed based on airfoil theory. The analysis treats the effect of time-varying wetted length on added mass and damping coefficient. When the reduced frequency becomes very small, the change in wetted length approaches displacement of the intersection of the planing surface and the undisturbed water surface. In the limiting case of zero frequency, the wetted length change reduces to zero.

84-1614

The Diffraction of Free-Surface Waves by a Slender Ship

P.D. Sclavounos

Massachusetts Inst. of Tech., Cambridge, MA, J. Ship Res., 28 (1), pp 29-47 (Mar 1984) 19 figs, 1 table, 31 refs

Key Words: Ships, Interaction: structure-fluid

A linear theory is presented for the scattering of small-amplitude monochromatic and unidirectional free-surface waves by a ship fixed at its mean advancing position. In an inner region close to the ship the hull geometrical slenderness is used to justify a quasi-two-dimensional approximation of the flow. The method of matched asymptotic expansions is then introduced to enforce the compatibility of the inner solution with the three-dimensional solution in the far field. The theory is shown to be uniformly valid for all wavelengths of practical interest and all angles of wave incidence.

84-1615

A Numerical Solution of Two-Dimensional Deep Water Wave-Body Problems

A. Nestegard and P.D. Sclavounos

Massachusetts Inst. of Tech., Cambridge, MA, J. Ship Res., 28 (1), pp 48-54 (Mar 1984) 13 figs, 14 refs

Key Words: Interaction: structure-fluid, Ships, Wave forces

A numerical technique is presented for the solution of deep water linear and time-harmonic wave-body-interaction problems in two dimensions. A mathematical boundary of circular shape surrounding the body is introduced in the fluid domain, thus defining two flow regions. A multipole expansion valid in the outer region is then matched to an integral representation of the solution in the inner region which is obtained by applying Green's theorem and by using the fundamental logarithmic singularity as the Green function. The method applies both to surface-piercing and submerged bodies. Numerical results are presented for the forced oscillations of three surface-piercing ship-like sections of regular shape.

AIRCRAFT

(Also see No. 1653)

84-1616

Helicopter Impulsive Noise: Theoretical and Experimental Status

F.H. Schmitz and Y.H. Yu

NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-A-9477, NASA-TM-84390, USAAVRADCOM-TR-83-A-2, 105 pp (Nov 1983)

AD-A136 987

Key Words: Helicopter noise

The theoretical and experimental status of helicopter impulsive noise is reviewed. The two major source mechanisms of helicopter impulsive noise are addressed: high-speed impulsive noise and blade-vortex interaction impulsive noise. A thorough physical explanation of both generating mechanisms is presented together with model and full-scale measurements of the phenomena. Current theoretical prediction methods are compared with experimental findings of isolated rotor tests.

84-1617

Rotor/Body Aerodynamic Interactions

M.D. Betzina, C.A. Smith, and P. Shinoda

NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-A-9500, NASA-TM-85844, 39 pp (Oct 1983)

AD-A135 040

Key Words: Helicopters, Rotors, Propeller blades, Wind tunnel testing, Aerodynamic loads

A wind-tunnel investigation was conducted in which independent, steady-state aerodynamic forces and moments were measured on a 2.24-m-diam, two-bladed helicopter rotor and on several different bodies. The objective was to determine the mutual interaction effects for variations in velocity, thrust, tip-path-plane angle of attack, body angle of attack, rotor/body position, and body geometry. This report presents the effects of various parameters on the interactions and discusses the difficulties encountered in determining the effect of the body on the rotor performance.

84-1618

Adaptive Inverse Control for Helicopter Vibration Reduction

S.A. Jacklin

NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-TM-84336, 19 pp (Sept 1983)

N84-11177

Key Words: Helicopter vibration, Vibration control

The reduction or alleviation of helicopter vibration will reduce maintenance requirements while at the same time increase ride quality and helicopter reliability. In forward flight, the helicopter's fuselage vibration spectrum tends to be dominated by multiples of the N/REV component. A way to use the method of adaptive inverse control to identify, in real-time, a controller capable of generating N/REV vibration of opposite phase to cancel the uncontrolled N/REV component is presented. Multicyclic feathering of blade pitch is the control considered.

84-1619
Shielding of Prop-Fan Cabin Noise by the Fuselage Boundary Layer

D.B. Hanson

Hamilton Standard, Div. of United Technologies, Windsor Locks, CT 06096, J. Sound Vib., 92 (4), pp 591-598 (Feb 22, 1984) 6 figs, 16 refs

Key Words: Aircraft noise, Interior noise, Noise barriers

Recent flight tests of a prop-fan (advanced technology turboprop) model mounted on a business aircraft revealed noise levels on the fuselage surface considerably lower than was expected from theoretical calculations and other test experience. In this paper the role of the fuselage boundary layer in shielding the surface from noise via classical refraction effects is examined.

84-1620
Influence of Physical and Air Traffic Conditions on Aircraft Noise Emission to the Ground (Einfluss der physikalischen und flugbetrieblichen Bedingungen auf die Fluglaermimmission am Boden)

U. Issermann

Max-Planck-Inst. fuer Stroemungsforschung, Goettingen, Fed. Rep. Germany, Rept. No. MPIS-11/1982, ISSN-0436-1199, 111 pp (Oct 1982)

N84-11159

(In German)

Key Words: Aircraft noise

The dependence of form and size of aircraft noise zones on the physical and air traffic conditions is investigated. The acoustic quantities required to determine the equivalent noise level are explained. A method to calculate the noise level curves is presented. The form of the noise spectrum has a strong effect on the damping of the waves in the atmosphere.

84-1621
Study of Noise Transmission through Double Wall Aircraft Windows

R. Vaicaitis

Modern Analysis, Inc., Ridgewood, NJ, Rept. No. REPT-3, NASA-CR-172182, 93 pp (June 1983)

N84-11884

Key Words: Aircraft noise, Aircraft windows, Interior noise

Analytical and experimental procedures were used to predict the noise transmitted through double wall windows into the cabin of a twin-engine G/A aircraft. The analytical model was applied to optimize cabin noise through parametric variation of the structural and acoustic parameters. The parametric study includes mass addition, increase in plexiglass thickness, decrease in window size, increase in window cavity depth, depressurization of the space between the two window plates, replacement of the air cavity with a transparent viscoelastic material, change in stiffness of the plexiglass material, and different absorptive materials for the interior walls of the cabin.

84-1622
Relationship Between Static, Flight, and Simulated Flight Jet Noise Measurements

R.S. McGowan and R.S. Larson

Pratt & Whitney Aircraft Group, East Hartford, CT, AIAA J., 22 (4), pp 460-464 (Apr 1984) 3 figs, 13 refs

Key Words: Aircraft noise, Jet noise, Noise measurement

Jet noise data are acquired in three different forms: static, flight, and simulated forward flight. Often data must be transformed from one type to one of the other two. A number of studies exist defining the relationship between these three types of measurements. These studies are deficient because they do not explicitly consider the jet noise source characteristics or do not clearly distinguish between mean square pressure, power spectral density, and one-third octave band sound pressure level measurements. In the current study, the relationships between static, subsonic flight, and subsonic simulated forward flight one-third octave band sound pressure level measurements were defined.

84-1623
Numerical Simulation of Transonic Flutter of a High-Aspect-Ratio

K. Isogai

Natl. Aerospace Lab., Tokyo, Japan, Rept. No. NAL/TR-776T, 21 pp (Aug 1983)

PB84-135177

Key Words: Aircraft wings, Flutter, Numerical analysis, Simulation

Numerical simulation of transonic flutter of a wind tunnel flutter model of a high-aspect-ratio transport wing with supercritical airfoil sections has been performed, by using the computer code USTF3 which solves the unsteady 3D full potential equation by a two-step semi-implicit time marching finite difference technique. In order to correct the mean steady-state location and strength of the shock wave, a 2D strip turbulent boundary layer technique has been incorporated into USTF3.

84-1624

Active Suppression of Aeroelastic Instabilities on a Forward-Swept Wing

T.E. Noll, F.E. Eastep, and R.A. Calico

Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH, J. Aircraft, 21 (3), pp 202-208 (Mar 1984) 16 figs, 17 refs

Key Words: Aircraft wings, Active vibration control, Wing stores

Analytical studies were conducted to investigate the potential of using feedback control systems for preventing multiple aeroelastic instabilities occurring simultaneously in close proximity on a forward-swept wing configuration. With the addition of wing mounted external stores, the classical bending/torsion flutter instability can be driven to lower airspeeds into the vicinity of aeroelastic instabilities such as divergence and body freedom flutter more commonly associated with a forward-swept wing. For these studies a typical forward-swept wing configuration, adversely mass balanced to create dynamic characteristics similar to those caused by adding external stores, was investigated.

84-1625

Aerodynamic Characteristics, Including Effect of Body Shape, of a Mach 6 Aircraft Concept

G.D. Riebe

NASA Langley Res. Ctr., Hampton, VA, Rept. No. L-15675, NASA-TP-2235, 32 pp (Dec 1983) N84-13164

Key Words: Aerodynamic loads, Geometric effects, Aircraft

Longitudinal aerodynamic characteristics for a hydrogen-fueled hypersonic transport concept at Mach 6 are presented. The model components consist of four bodies with identical longitudinal area distributions but different cross-sectional shapes and widths, a wing, horizontal and vertical tails, and a set of wing-mounted nacelles simulated by slid bodies on the wing upper surface. Lift-drag ratios were found to be only slightly affected by fuselage planform width or cross sectional shape.

84-1626

Numerical Calculation of Unsteady Transonic Potential Flow over Three-Dimensional Wings with Oscillating Control Surfaces

K. Isogai and K. Suetsugu

Natl. Aerospace Lab., Tokyo, Japan, AIAA J., 22 (4), pp 478-485 (Apr 1984) 8 figs, 23 refs

Key Words: Aircraft wings, Aerodynamic loads

Numerical calculations of the unsteady transonic potential flow over three-dimensional wings with oscillating control surfaces are performed. For this purpose, a new grid system, which is appropriate for solving the control surface problems, is introduced into the computer code USTF3, which solves the unsteady three-dimensional full potential equation by a two-step semi-implicit time-marching technique. To validate the code, the unsteady pressure distributions on the NLR swept tapered wing with an inboard control surface and on the RAE swept tapered wing with a part-span control surface are calculated and compared with those of existing theories and experimental data.

84-1627

A Method for Predicting Low-Speed Aerodynamic Characteristics of Transport Aircraft

L.E. Murillo and J.H. McMasters

Boeing Commercial Airplane Co., Seattle, WA, J. Aircraft, 21 (3), pp 168-174 (Mar 1984) 12 figs, 4 refs

Key Words: Aircraft, Aerodynamic loads, Computer programs

A preliminary design level methodology for predicting the global aerodynamic characteristics of transport aircraft in low-speed/high-lift configurations has been developed, based on recent advances in computational aerodynamics and analysis methods. The new method involves two economical, user oriented, computer programs. One, an advanced lifting-surface theory for the potential flow analysis of swept-wing/body combinations with multi-element high-lift devices, provides the basic theoretical structure. The second program combines potential flow analysis results with available data from previous airplane models to predict the performance of new designs.

84-1628

Gust Alleviation (Boenabminderung)

G. Bruening

Lehrstuhl fuer Flugmechanik und Flugregelung, Technische Univ., Munich, Fed. Rep. Germany, 167 pp (1983)
N84-11180
(In German)

Key Words: Aircraft, Wind-induced excitation

Gust alleviation concepts were studied numerically on a Boeing 707 aircraft with autopilot. Stochastic gust processes were studied in the frequency domain. The calculations show that the best solution is the control of the pitch position and the pitch velocity by using the autopilot mode pitch-hold. It is shown that additional control systems (e.g. transverse control) can substantially reduce disturbance.

84-1629

Crashworthy Cyclic Control Stick

D.K. Eisentraut and R.E. Zimmerman

Simula, Inc., Tempe, AZ, Rept. No. TR-83412, USAAVRADCOM-TR-83-D-23, 78 pp (Nov 1983)
AD-A135 150

Key Words: Crash research (aircraft), Helicopters

In helicopter crashes, a potential source of injury is crewmember impact with the cyclic control stick. This program sought to alleviate that hazard through the development of a crashworthy cyclic control stick retrofittable to the UH-60A Black Hawk and AH-1S Cobra helicopters. Concepts examined for this application included those employing frangible, deformable, telescoping, collapsing, and seperating sticks, as well as the cutters. The selected design was a slip joint separating stick, with an energy absorber, activated by crewmember impact. Four prototypes were fabricated and tested, both statically and dynamically.

84-1630

Structural Response of Transport Airplanes in Crash Situations

R.G. Thomson and C. Caiafa

Fed. Aviation Admn. Technical Ctr., Atlantic City, NJ, Rept. No. DOT/FAA/CT-83/42, NASA-TM-85654, 123 pp (Nov 1983)
AD-A135 884

Key Words: Crash research (aircraft), Crashworthiness

This report highlights the results of contractural studies of transport accident data undertaken in a joint research program sponsored by the FAA and NASA. From these accident data studies it was concluded that the greatest potential for improved transport crashworthiness is in the reduction of fire related fatalities. Accident data pertaining to fuselage integrity, main landing gear collapse, fuel tank rupture, wing breaks, tearing of tank lower surfaces, and engine pod scrubbing are discussed.

84-1631

Vertical Drop Test of a Transport Fuselage Center Section Including the Wheel Wells

M.S. Williams and R.J. Hayduk

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-85706, 59 pp (Oct 1983)
N84-12531

Key Words: Aircraft, Dynamic tests, Drop tests (impact tests)

A Boeing 707 fuselage section was drop tested to measure structural, seat, and anthropomorphic dummy response to vertical crash loads. The specimen had nominally zero pitch, roll and yaw at impact with a sink speed of 20 ft/sec. Results from this drop test and other drop tests of different transport sections will be used to prepare for a full-scale crash test of a B-720.

MISSILES AND SPACECRAFT

84-1632

Effect of Mass and Stiffness Changes on the Damping Factor in a Large Space Structure as Represented by the CSDL 2 Model

D.E. Olsen

School of Engrg., Air Force Inst. of Tech., Wright-Patterson AFB, OH, Rept. No. AFIT/GSO/AA/83D-2, 132 pp (Dec 1983)
AD-A136 984

Key Words: Spacecraft equipment, Damping coefficients

This investigation was undertaken to determine the sensitivity of the damping factor in a large space structure (LSS) to small changes in nonstructural mass and structural element stiffness. Revision 3 of the ACOSS 2 model, developed by the Charles Stark Drapes Laboratory, Inc. was used as the model of the LSS. Various combinations of the mirror masses in this large space telescope were varied by up to 10%, selected structural elements were stiffened by increasing their cross-sectional areas by 10 and 50%, and, finally, two structural elements in the middle of the telescope were stiffened to represent the addition of a lumped mass located away from the control system sensors and actuators. A control system of 21 collocated sensors and actuators, positioned at the top and bottom of the telescope, was used in this analysis. The analysis was accomplished using NASTRAN for the finite element analysis, and, after selecting certain vibration modes for further study, the complex conjugate pairs used to determine the damping factors were calculated.

BIOLOGICAL SYSTEMS

HUMAN

84-1633

Thresholds of Perception of Vibration in Recumbent Men

T. Miwa, Y. Yonekawa, and K. Kanada
Dept. of Human Environmental Engrg., Natl. Inst. of Industrial Health, 21, Nagao, 6 Chome Tama-Ku, Kawasaki (214) Japan, J. Acoust. Soc. Amer., 75 (3), pp 849-854 (Mar 1984) 6 figs, 14 refs

Key Words: Vibration excitation, Human response

The thresholds of perception of vibration by recumbent men are a significant index for the governmental agency concerned with regulation of vibration exposure. The thresholds of perception of continuous sinusoidal vibrations and single and multiple bursts of sinusoidal vibrations in the horizontal and vertical directions were investigated in recumbent men. It was found that the threshold curves, as a function of the frequency, had different characteristics for vertical vibrations than for horizontal vibrations in the recumbent position.

84-1634

Low Frequency Noise Annoyance Assessment by Low Frequency Noise Rating (LFNR) Curves

N. Broner and H.G. Leventhall
Vipac & Partners Pty Ltd., 30-32 Clarement St., South Yarra, Victoria, Australia 3141, J. Low Frequency Noise Vib., 2 (1), pp 20-28 (1983) 6 figs, 2 tables, 47 refs

Key Words: Industrial facilities, Low frequencies, Noise generation, Human response

Over recent years, it has become apparent that low frequency noise annoyance is more widespread than originally believed. Annoyance has occurred where the emitted noise is unbalanced towards the low frequencies even though the dB(A) level has been low. Following laboratory experiments carried out as part of an investigation into low frequency annoyance combined with field annoyance data, the low frequency noise rating curves are proposed for the assessment of low frequency noise annoyance complaints.

84-1635

Patterns of Behaviour in Dwellings Exposed to Road Traffic Noise

J. Lambert, F. Simonnet, and M. Vallet
Institut de Recherche des Transports, Centre d'Evaluation et de Recherche des Nuisances et de l'Energie, 109 Avenue Salvador Allende, 69500 Bron, France, J. Sound Vib., 92 (2), pp 159-172 (Jan 22, 1984) 9 figs, 4 tables, 16 refs

Key Words: Buildings, Traffic noise, Human response

An inquiry involving a total of 1500 subjects residing in 15 different sites in the conurbations of Lyon and Marseilles was carried out in 1979 with a view to determining the behaviour and attitudes of people with regard to traffic noise. The main purpose of the inquiry was to identify the objective reactions to the traffic noise and to determine how such reactions varied with the noise level, with account taken of the socio-economic characteristics of the subjects (age, income, owner occupier or tenant, etc.).

84-1636

Dynamic Response of the Human Thorax When Subjected to Frontal Impact

K.H. Digges
Dept. of Engrg. Science, Oxford Univ., UK, Rept. No. OUEL-1453/83, 39 pp (1983)
PB84-136910

Key Words: Collision research (automotive), Impact tests, Human response

The purpose of this report is to document a model of the human thorax which has been used on a VAX-2 computer, and to present some typical results produced by the model. The model uses physical parameters based upon tests re-

ported in the literature. The test specimens include human cadavers, living human volunteers, and living and dead swine.

84-1637
Mathematical Model of the Human Thorax When Subjected to Frontal Impact During an Automobile Crash
K.H. Digges
Oxford Univ., UK, Rept. No. OUEL-1454/83, 40 pp (Mar 1983)
PB84-137173

Key Words: Collision research (automotive), Impact tests, Human response, Mathematical models

The purpose of this report is to document a model of the human thorax in an automobile crash which has been used on a VAX-2 computer and to present some typical results produced by the model. The model uses physical parameters based upon tests reported in the literature. Tests to develop the characteristics of the human thorax have been reported. The present report summarizes tests of automobiles to determine the engineering properties of vehicle interior. These test results, along with crash tests of complete vehicles, are used to model the vehicle interior and the crash acceleration pulse of the vehicle.

84-1638
Effects of Rear Seat Passengers on Front Seat Occupants in Frontal Impacts
A. K. Roberts
Transport and Road Res. Lab., Crowthorne, UK, Rept. No. TRRL/LR-1079, 30 pp (1983)
PB84-137991

Key Words: Collision research (automotive), Impact tests, Human response

This report describes a series of 50 km/hr frontal impact tests carried out in an estate car body shell on the TRRL impact test rig. The aim of the study was to determine the effect of a rear unrestrained adult passenger on a restrained front seat occupant and to estimate the magnitude of any effect. The importance of occupant restraint is clearly demonstrated.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS
(Also see No. 1872)

84-1639
Energy Transformation by Passenger Cars During Frontal Collisions (Energieumsetzung von Personenkraftwagen beim Frontalaufprall)
M. Rauser and M. Grossmann
Automobiltech. Z., 85 (9), pp 553-559 (Sept 1983)
9 figs, 10 refs
(In German)

Key Words: Energy absorption, Collision research (automotive)

In order to obtain a quantitative description of the energy absorbed by vehicles with front engines and rear-wheel drive during a frontal crash, tests were performed at a research and development center using production cars, modified vehicles and subassemblies. According to the energy balance obtained by means of a two-mass model, the kinetic energy released during a frontal collision at 50 km/h is absorbed by the front structure (79%), by the drive unit (12%), and by the fire wall (9%). The energy absorbed by the front structure is distributed as follows: 72% by the longitudinal members, 23% by the wheelhousings, and 5% by the fenders. Based on these findings, crush tests can be performed with body subassemblies in order to determine the respective energy absorption capacities to be expected during a dynamic crash and thus to give approximate consideration to occupant protection at a very early stage of body development.

84-1640
Tunable Damper for an Acoustic Wave Guide
S.C. Rogers
Dept. of Energy, Washington, DC, U.S. Patent Application No. 6-435 797, 14 pp (Oct 1982)
DE83018015

Key Words: Dynamic vibration absorption (equipment), Sound waves, Waveguide analysis

A damper for tunably damping acoustic waves in an ultrasonic waveguide is provided which may be used in a hostile environment such as a nuclear reactor. The area of the waveguide, which may be a selected size metal rod in which acoustic waves are to be damped, is wrapped, or surrounded, by a mass of stainless steel wool. The wool wrapped portion is then sandwiched between tuning plates, which may also be stainless steel, by means of clamping screws which may be adjusted to change the clamping force of the sandwiched assembly along the waveguide section.

84-1641

Analysis of Limit Cycle Oscillations in a Magnetic Suspension System Using the Describing Function Method

L.O. Kehinde

Univ. of Ife, Ile-Ife, Nigeria, Intl. J. Engrg. Sci., 22 (4), pp 419-437 (1984) 14 figs, 5 refs

Key Words: Magnetic suspension techniques

This paper presents an analysis of limit cycle oscillations observed in a magnetic suspension system which utilizes an optical transducer. Stability conditions for certain nonlinearities are obtained using the describing function approach and these conditions are later verified by the stability criterion of Gelb and Van der Velde in the saturation nonlinearity.

84-1642

Semi-Active Control of Wheel Hop in Ground Vehicles

D.L. Margolis

Univ. of California, Davis, CA 95616, Vehicle Syst. Dynam., 12 (6), pp 317-330 (Dec 1983) 10 figs, 7 refs

Key Words: Suspension systems (vehicles), Active isolation

A two degree-of-freedom vehicle model is developed which incorporates passive, active, and semi-active secondary suspensions. The model is used to demonstrate the trade-offs which are inherent in attempting to provide desirable sprung weight isolation while at the same time controlling unsprung weight motions. A linear model is used first in order to compare passive and active suspensions in an analytically understandable configuration. The semi-active suspension is inherently nonlinear and is compared to the others through computer simulation.

84-1643

Auto and Truck Suspension Systems. June, 1970 - November 1983 (Citations from the Engineering Index Data Base)

NTIS, Springfield, VA, 175 pp (Nov 1983)
PB84-853274

Key Words: Suspension systems (vehicles), Automobiles, Trucks, Bibliographies, Fatigue life

This bibliography contains 282 citations concerning the effect of suspension systems on the performance of motor vehicles. Topics include shock absorbers, steering stability, and load leveling, as well as the characteristics of both leaf and coil springs. Materials considerations such as fatigue and wear are also discussed.

84-1644

Modal Analysis of Rigid Bodies Supported by Low Frequency Pneumatic Vibration Isolators

H.D. Sigel and G.C.Pardoen

Newport Corp., SAE Paper No. 821481 (SP-529)

Key Words: Modal analysis, Isolators, Frequency response

Classical techniques for determining accurate frequencies and modes of a rigid body supported by pneumatic vibration isolation mounts were deemed unsatisfactory. It was found that the isolator's transfer functions were nonlinear and exhibited frequency dependent stiffness and damping characteristics. To overcome these shortcomings a computer model of the isolator's frequency response was developed by curve fitting a Laplace polynomial to the experimentally derived transfer functions. By mathematically combining the isolator's response characteristics with a variety of rigid bodies the total system's performance under a number of laboratory configurations could be efficiently predicted.

84-1645

How to Select Power-Train Isolators for Good Performance and Long Service Life

R. Racca, Sr.

Barry Controls/a Unit of Barry Wright Corp., SAE Paper No. 821095

Key Words: Isolators, Elastomers, Driveline vibrations

This paper presents those factors that must be considered in selecting elastomeric isolators for power-train applications in order to develop an isolation system that will be both effective and provide sufficient service life. Those factors include the dynamic modes that are the most disturbing, support structure requirements, isolator location and orientation, the advantage of decoupled modes, stability considerations, environmental factors, factors that affect fatigue life, and analysis procedure.

84-1646

An Adaptive Controller for Multivariable Active Noise Control

A.D. White and D.G. Cooper
The Plessey Co., Plessey Marine Res. Unit, Wilkinthroop House, Templecombe, Somerset, UK, Appl. Acoust., 17 (2), pp 99-109 (1984) 7 figs, 1 table

Key Words: Rotating machinery, Active noise control, Vibration control

The control of vibration through the mounts of rotating machines can be achieved by actively generating cancelling forces from shakers located close to the mounts. The cancelling waveforms cannot simply be an anti-phase copy of the original waveform as each shaker affects the vibration at mounts other than the one at which it is cancelling. This paper describes an approach to this multivariable control problem which measures all shaker to sensor transfer functions to give a shaker transfer function matrix, M(f).

84-1647

The Arrangement of Sound Absorbers for Noise Reduction -- Results of Model Experiments at 1:16 Scale

R.J. Orlowski
Dept. of Architecture, Univ. of Cambridge, 1 Scroope Terrace, Trumpington St., Cambridge CB2 1PX, UK, Noise Control Engrg. J., 22 (2), pp 54-60 (Mar/Apr 1984) 16 figs, 5 refs

Key Words: Industrial facilities, Noise reduction, Sound waves, Wave absorption, Absorbers (materials), Porous materials

A widespread method for reducing noise in factories is the use of arrays of functional absorbers suspended above the working area. A series of experiments was conducted at model-scale (1:16) on various arrangements of absorbers. Data were collected for use in an investigation of the effectiveness of such noise control techniques in factories. While the experimentation was done at model-scale, the data obtained are directly applicable to full-scale conditions and therefore of potential interest to noise control engineers.

84-1648

Baffle-Type Cooling System: a Case Study

Y.S. Wang and J.W. Sullivan
Outboard Marine Corp, 300 Sea-Horse Dr., Waukegan, IL 60085, Noise Control Engrg. J., 22 (2), pp 61-67 (Mar/Apr 1984) 14 figs, 1 table, 9 refs

Key Words: Baffles, Coding systems, Noise reduction

An investigation was made of a baffle-type cooling system. The baffle acts not only to cool the machine, but also as a noise control feature, blocking the sound radiating from the machine. A theoretical model is presented in this paper to assist in determining optimal baffle location and absorption material used in the baffle system for both cooling efficiency and noise reduction. The case of a portable air compressor is evaluated.

SPRINGS

(Also see No. 1691)

84-1649

Developments in Spring Testing

J.R. Ellis
Ellis Kirkaldy Engineering Ltd., Chart. Mech. Engr., 31 (3), pp 49-51 (Mar 1984) 4 figs

Key Words: Helical springs, Springs, Testing techniques

A new concept in the automatic testing of helical compression and tension springs is described. The system's basic elements are: mechanical assembly for compressing/extending springs; measuring elements for force, length and time; driving unit; interface between a, b, c, and the computer; computer hardware; software for operating and analysis of tests, and special tools.

TIRES AND WHEELS

(Also see No. 1602)

84-1650

Railway Wheel Squeal (2nd Report, Mechanism of Specific Squeal Frequency)

M. Nakai, Y. Chiba, and M. Yokoi
Kyoto Univ., Yoshida-honmachi, Sakyo-ku, Kyoto, Japan, Bull. JSME, 27 (224), pp 301-308 (Feb 1984) 10 figs, 6 tables, 7 refs

Key Words: Wheels, Railway wheels, Noise generation

The mechanism of specific squeal frequency was investigated using an apparatus consisting of a steel rod and a thin steel disk. Squeals of higher modes occur in large rods. Squeal is generated at specific contact positions on a rod. From the theoretical results, it was found that a squeal of the frequency near the contact frequency of the rod and disk occurs.

84-1651

Study on the Mechanism of Noise Generation of Railway Wheel and Its Countermeasure (5th Report, Flexural Vibration and Noise of a Spoke Type Wheel)

H. Matsuhisa, T. Hasegawa, and S. Sato

Kyoto Univ., Sakyo-ku, Kyoto, Japan, Bull. JSME, 27 (224), pp 295-300 (Feb 1984) 14 figs, 3 tables, 7 refs

Key Words: Wheels, Railway wheels, Noise generation, Flexural vibration

The noise of a train running over sharp curves is mainly caused by flexural vibration of the wheels. Characteristics of the noise radiation of the spoke type wheel is experimentally investigated, and it is found that the noise generated by spoke type wheel is considerably less than that of the web type wheel. In this analysis the wheel is assumed to be an annular Mindlin plate which is elastically supported by springs which simulate the spokes.

BLADES

(Also see Nos. 1564, 1861)

84-1652

Graphics Subsystem Retrofit Design for the Bladed-Disk Data Acquisition System

R.R. Carney

NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. E-1760, NASA-TM-83510, 74 pp (Jan 1983)
N84-12730

Key Words: Blades, Propeller blades, Vibration recording, Data recorders, Graphic methods

A graphics subsystem retrofit design for the turbojet blade vibration data acquisition system is presented. The graphics subsystem will operate in two modes permitting the system operator to view blade vibrations on an oscilloscope type of display. The first mode is a real-time mode that displays only gross blade characteristics, such as maximum deflections and standing waves. This mode is used to aid the operator in determining when to collect detailed blade vibration data. The second mode of operation is a post-processing mode that will animate the actual blade vibrations using the detailed data collected on an earlier data collection run. The operator can vary the rate of payback to view differing characteristics of blade vibrations.

84-1653

Investigation of the Effect of Blade Sweep on Rotor Vibratory Loads

F.J. Tarzanin, Jr. and R.R. Vlaminck

Boeing Vertol Co., Philadelphia, PA, Rept. No. NASA-CR-166526, 134 pp (Oct 1983)
AD-A135 603

Key Words: Propeller blades, Helicopters, Geometric effects, Vibratory stresses

The effect of helicopter rotor blade planform sweep on rotor vibratory hub, blade, and control system loads has been analytically investigated. The importance of sweep angle, sweep initiation radius, flap bending stiffness and torsion bending stiffness is discussed. The mechanism by which sweep influences the vibratory hub loads is investigated.

84-1654

Time Domain Analysis of a Rigid Two-Bladed Fully Gimballed Helicopter Rotor with Circulation Control

P.S. Montana

David W. Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD, Rept. No. DTNSRDC-83/081, AERO-1282, 88 pp (Dec 1983)
AD-A136 947

Key Words: Propeller blades, Helicopters, Time domain method

An analytic investigation was made to determine the dynamic properties of a two-bladed rigid fully gimballed helicopter rotor incorporating circulation control airfoils and tip jet propulsion. A time domain analysis was developed which provided the capability of using nonlinear airfoil aerodynamics and arbitrary rotor physical characteristics. The effects of feather principal axis of inertia location, horizontal gust disturbances, and feedback control on rotor stability were assessed.

84-1655

Theoretical and Experimental Dynamic Stall Investigations on a Rotor Blade Tip

W. Geissler

Deutsche Forschungs- und Versuchsanstalt f. Luft- und Raumfahrt e.V., Freiburg im Breisgau, Fed. Rep. Germany, 6 pp (1982) (Pres. at Symp. on Numerical and Physical Aspects of Aerodynamic Flows (2nd), Jan 17-20, 1983, California State Univ., Long Beach, CA)

AD-P001 950

Key Words: Blades, Propeller blades, Aerodynamic loads

Theoretical and experimental investigations have been carried out on oscillating blade tips at moderate and high steady main incidences and oscillation amplitudes. Some selected data of these tests are compared with a previously developed prediction method based on potential theory to investigate the main effects of viscosity in different domains of dynamic stall. A simple correction procedure is described to take into account the main effects of viscosity on the unsteady airloads. To get a more detailed insight into the beginning of unsteady separation on oscillatng profiles a finite-difference procedure has been developed to calculate the unsteady boundary-layer equations. This method has been applied to the oscillating flat plate problem as a first step.

84-1656

Holographic Interferometry Technique for Measuring Transonic Flow Near a Rotor Blade

J.K. Kittleson

NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-A-9432, NASA-TM-84405, USAAVRADCOM-TR-83-A-10, 24 pp (Aug 1983)

AD-A134 040

Key Words: Blades, Propeller blades, Helicopters, Interferometric techniques, Holographic techniques

A technique that uses holographic interferometry to record the first interferograms of the flow near a hovering transonic rotor blade is presented. A pulsed ruby laser is used to record interferograms of a 2-ft-diam field of view near a rotor tip operating at a tip Mach number of 0.09. Several interferograms, recorded along planes perpendicular to the rotor's tip-path-plane at various azimuthal angles around the flow, are presented. These interferograms yield quantitative information about shock structure and location, flow separation, and radiated noise that will help helicopter researchers understand the complexities of the flow around high-speed rotor blades and thus improve performance and reduce noise.

84-1657

Finite Element Dynamic Analysis of a Rotating Turbine Blade

H.T. Belek and A. Tamura

Istanbul Technical Univ., Turkey, ASME-83-GTJ-22

Key Words: Blades, Turbine blades, Rotating structures, Finite element technique

A finite element dynamic analysis of a rotating turbine blade is performed using the isoparametric shell elements. The number of Gauss integration points on the element surface along the natural coordinate directions is varied and the effects on the natural frequencies is investigated. Hence the optimum Gauss integration order is determined.

84-1658

Flexible Conformable Clamps for a Machining Cell with Applications to Turbine Blade Machining

E. Kurokawa

Robotics Inst., Carnegie-Mellon Univ., Pittsburgh, PA, Rept. No. CMU-RI-TR-83-16, 34 pp (May 1983)

AD-A134 942

Key Words: Blades, Turbine blades, Natural frequencies

A flexible, conformable clamping scheme for a steam turbine blade machining cell is discussed. Experiments that have been carried out to investigate the clamping efficiency of this novel design are also described. Flexible fixtures for turbine blade machining have been developed and installed to demonstrate the reduction of human intervention for workpiece setup in a laboratory. The key features of the clamp design and the cell configuration are described. The theory of vibration is reviewed and the experimental results of damped natural frequencies of the clamped blade are presented.

84-1659

Effects of Static Friction on the Forced Response of Frictionally Damped Turbine Blades

A. Sinha and J.H. Griffin

Carnegie-Mellon Univ., Pittsburgh, PA 15213, J. Engrg. Gas Turbines Power, Trans. ASME, 106 (1), pp 65-69 (Jan 1984) 9 figs, 13 refs

Key Words: Coulomb friction, Blades, Turbine blades, Damped structures

The effect of static friction on the design of flexible blade-to-ground vibration dampers used in gas turbine engines is investigated. Analytical results are compared with those from the conventional numerical time integration method. In addition, an efficient time integration algorithm is described which can be used to predict the peak displacements of the transition solution without tracing the whole waveform, a useful procedure when no harmonic steady-state solution exists. The conditions under which blade response can be adequately modeled by simulating only dynamic friction are established.

84-1660

Growian-Rotorblades: Production Development, Construction and Test

H.M. Thiele

Bundesministerium fuer Forschung und Technologie, Bonn-Bad Godesberg, Fed. Rep. Germany, Rept. No. BMFT-FB-T-83-111, 76 pp (June 1983)

DE83751247

(In German)

Key Words: Rotor blades (turbomachinery), Turbine blades, Vibration tests, Qualification tests

This project deals with the development and construction of the 50 m rotor blades of the 3 MW Growian-Windturbine. The design concept shows a load carrying untwisted steel spar and a GFRP-skin which leads the aerodynamic forces into the spar. After construction of a test blade static loading tests and a dynamic vibration test were performed. Fatigue tests at critical weldings as well as at the connection between spar and panel were also performed.

84-1661

Measurements of Self-Excited Rotor-Blade Vibrations Using Optical Displacements

A.P. Kurkov

NASA Lewis Res. Ctr., Cleveland, OH 44135, J. Engrg. Gas Turbines Power, Trans. ASME, 106 (1), pp 44-49 (Jan 1984) 13 figs, 7 refs

Key Words: Blades, Fan blades, Flutter

During the operation of a turbofan engine at part speed, near stall, and elevated inlet pressure and temperature, several vibratory instabilities were excited simultaneously on the first fan rotor. The torsional and bending contributions to the main flutter mode were resolved by using casing-mounted optical displacement sensors. Strain-gage spectra were used to identify other instabilities in the blade-deflection spectra. The characteristics of optical-displacement spectra and their role of monitoring rotor-blade vibrations are discussed.

84-1662

Structural Response Due to Blade Vane Interaction

R.L. Jay, J.C. MacBain, and D.W. Burns

Detroit Diesel Allison Div. of General Motors, Indianapolis, IN 46206, J. Engrg. Gas Turbines Power, Trans. ASME, 106 (1), pp 50-56 (Jan 1984) 17 figs, 4 refs

Key Words: Blades, Vanes, Disks, Turbomachinery, Experimental data, Interaction: rotor-stator

The structural response of a bladed turbine disk due to excitation from an upstream stator row was measured using strain gages. Rig testing performed in a realistic aerodynamic environment was preceded by a static vibratory search in which individual blade frequencies and system modes were identified by strain response and holography. In the rig testing special emphasis was placed on identifying the dynamic response resulting from the interaction between the vanes and blades. An analytical description of the forcing function which results from the difference between the number of blades and the number of vanes is presented and correlated with detailed blade responses both in terms of amplitude and interblade phasing.

84-1663

Acoustic Resonances and Blade Vibration in Axial Flow Compressors

R. Parker

Univ. College of Swansea, Singleton Park, Swansea SA2 8PP, Wales, J. Sound Vib., 92 (4), pp 529-539 (Feb 22, 1984) 7 figs, 10 refs

Key Words: Blades, Compressor blades, Acoustic excitation, Resonant response

A study is made of the conditions in which vibration of the blades of an axial flow compressor can be excited by acoustic resonances of the annulus. Such resonances can be generated by stalled blade rows and therefore occur during part speed operation.

84-1664

Blade Vibration Measurements on Centrifugal Compressors by Means of Telemetry and Holographic Interferometry

U. Haupt and M. Rautenberg

Univ. of Hannover, Hannover, W. Germany, J. Engrg. Gas Turbines Power, Trans. ASME, 106 (1), pp 70-78 (Jan 1984) 24 figs, 4 refs

Key Words: Blades, Compressor blades, Centrifugal compressors, Vibration measurement, Telemetry, Holographic techniques, Interferometric techniques

Blade vibration measurements were carried out on a high-pressure, high mass-flow centrifugal compressor to determine the excitation mechanism. For the experimental investigation, semiconductor strain gages with a multichannel telemetry system were used. The measuring points on the blades were chosen using the results of a stress calculation for the vibrating blade by means of the FE-method. A research program was started with blade vibration measurements in different operating ranges of the compressor and with two types of diffusers. Results are presented for the blade excitations obtained by throttling the compressor at various rotational speeds and for the cases of passing resonances by increasing the rotational speed at constant throttle valve position.

84-1665

Dynamic Analysis of Practical Blades with Shear Center Effect

V. Karadağ

Technical Univ. of Istanbul, Macka-Istanbul, Turkey, J. Sound Vib., 92 (4), pp 471-490 (Feb 22, 1984) 8 figs, 11 tables, 32 refs

Key Words: Blades, Natural frequencies, Mode shapes, Finite element technique

Shear center effects on the natural frequencies and mode shapes of rotating and nonrotating practical blades are considered. An 18 degrees of freedom thick beam finite element is developed. Bending and shear force displacements and slopes, and torsional displacements are taken as degrees of freedom at both ends of the element. Total blade deflection slopes are considered as composed of bending and shear force deflection slopes in calculations of blade strain and kinetic energy. This element is compared with the existing thin and thick beam finite elements, and theoretical models. Results obtained for the vibration characteristics of rotating and nonrotating nonuniform aerofoil cross-sectioned blades are compared with the available calculated and experimental values.

84-1666

Vibrations of Blades with Variable Thickness and Curvature by Shell Theory

J.K. Lee, A.W. Leissa, and A.J. Wang

Ohio State Univ., Columbus, OH 43210 J. Engrg. Gas Turbines Power, Trans. ASME, 106 (1), pp 11-16 (Jan 1984) 5 figs, 5 tables, 22 refs

Key Words: Blades, Variable cross section, Shells, Natural frequencies, Mode shapes, Ritz method

A procedure for analyzing the vibrations of rotating turbomachinery blades has been previously developed. This procedure is based upon shallow shell theory, and utilizes the Ritz method to determine frequencies and mode shapes. However, it has been limited heretofore to blades of uniform thickness, uniform curvature, and/or twist and rectangular planform. The present work shows how the procedure may be generalized to eliminate the aforementioned restrictions. Nonrectangular planforms are dealt with by a suitable coordinate transformation.

BEARINGS

(Also see Nos. 1841, 1843, 1844)

84-1667

A Study of EHD Lubrication in a Journal Bearing with Piezoviscous Lubricants

S.C. Jain, R. Sinhasan, and D.V. Singh

Univ. of Roorkee, Roorkee, 247667, India, ASLE, Trans. 27 (2), pp 168-176 (Apr 1984) 14 figs, 22 refs

Key Words: Bearings, Journal bearings, Elastohydrodynamic properties

The deformation of a bearing, which can be of the order of the fluid film thickness when the bearing operates at large eccentricities, may affect the performance appreciably, and all the more so if the viscosity of the lubricant changes with pressure. In this paper, matched solutions for pressure distribution and the bearing displacement field, taking into account the combined effects of bearing liner deformation as well as change in viscosity of the lubricant, are obtained by solving the respective governing equations using a suitable iteration scheme for eccentricity ratios up to unity. The performance characteristics of the journal bearing and their variations with bearing flexibility, are studied with reference to eccentricity ratio and a deformation coefficient which is a measure of the flexibility of bearing shell.

84-1668

Modal Analysis and Error Estimates for Linearized Finite Journal Bearings

E. Hashish and T.S. Sankar

SPAR Aerospace Ltd., Montreal, Quebec, Canada, J. Vib., Acoust., Stress, Rel. Des., Trans. ASME, 106 (1), pp 100-106 (Jan 1984) 9 figs, 12 refs

Key Words: Bearings, Journal bearings, Modal analysis, Linearization methods, Error analysis

The linearized model of a rigid symmetric rotor with finite bearings is solved using modal analysis. Important parameters of the finite bearing system are evaluated and these include the logarithmic decrement, damped natural frequencies, complex frequency response functions, and inclination angles of the orbits with the load direction. A chart of error measures giving the deviation of the linearized bearing stiffness and damping from those of the actual nonlinear system is provided.

84-1669

Theoretical Considerations of Molecular Mean Free Path Influenced Slip in Self-Acting Gas-Lubricated Plain Journal Bearings

M. Malik

Univ. of Roorkee, India, IMechE, Proc., 198 (4), pp 25-31 (1984) 10 figs, 4 tables, 10 refs

Key Words: Bearings, Journal bearings

The purpose of this paper is to study the effect of slip under the influence of molecular mean free path on the steady state and dynamic performance characteristics of plain gas journal bearings. The theoretical investigations have been made over a wide range of compressibility numbers.

84-1670

The Dynamical Behaviour of Externally Pressurized Gas-Lubricated Unloaded Porous Journal Bearings

M. Malik and C.M. Rodkiewicz

Univ. of Alberta, Edmonton, Alberta, Canada, IMechE, Proc., 198 (4), pp 33-41 (1984) 8 figs, 1 table, 18 refs

Key Words: Bearings, Journal bearings

In many practical applications, such as with vertical rotors, journal bearings operate with nearly zero eccentricities. In such situations the externally pressurized gas-lubricated porous bearings can offer a viable alternative to the self-acting gas and oil bearings which are generally prone to film induced instabilities under lightly loaded conditions. This paper presents a thorough investigation of the dynamical behavior of unloaded externally pressurized gas porous bearings. An attempt is made to bring out clearly the effect of the more important design variables on the dynamic performance of the bearings.

84-1671

Minimization of the Variance in Oil-Film Damping Coefficient Estimates

M.N. Sahinkaya, O.S. Turkay, and C.R. Burrows

Univ. of Strathclyde, Glasgow, UK, ASME Paper No. 83-WA/DSC-6

Key Words: Bearings, Damping coefficients, Frequency domain method

The frequency-domain algorithm developed by the authors to estimate oil-film bearing coefficients uses a least squares estimator and produces the variances and confidence bounds for the estimates. The variances can be minimized by correct design of the experimental procedure as well as by the data analysis package.

84-1672

A Study on Angular Stiffness and Damping Properties of Externally Pressurized Gas Thrust Bearing with Surface-Restriction Compensation

H. Yabe, T. Shiokawa, and H. Mori

Kyoto Univ., Yoshida-Honmachi, Sakyo-ku, Kyoto, Japan, Bull. JSME, 26 (222), pp 2251-2257 (Dec 1983) 13 figs, 4 refs

Key Words: Bearings, Stiffness coefficients, Damping coefficients

An externally pressurized gas-lubricated thrust bearing with surface-restriction compensation is analyzed theoretically for an angular displacement scheme applying an equivalent clearance model, which considers an equivalent recessed thrust bearing neglecting the local flow components in the bearing clearance, yielding angular stiffness and damping coefficient. The design criterion of the bearing with surface-restriction compensation is also discussed from the results of theoretical calculations for angular stiffness and damping coefficient.

84-1673

Dynamic Characteristics and Stability of a Helical-Grooved Floating-Ring Bearing Operated in Turbulent Regime

C.Y. Chow

Schenectady, NY 12303, ASLE, Trans., 27 (2), pp 154-163 (Apr 1984) 17 figs, 11 refs

Key Words: Bearings, Stiffness coefficients, Damping coefficients

The performance of a helical-grooved floating-ring bearing operated in turbulent regime has been studied. The load capacity of this type of bearing is proportional to the sum of speeds of journal and ring whereas the power loss is approximately proportional to the difference of these speeds. Numerical results of dynamic stiffness and damping, the critical mass plus the static performance are presented in graphical forms or tables to facilitate design of this type of bearing. Performance comparisons are made with respect to those of a single journal bearing.

84-1674

An Externally Pressurized Supersonic Gas Thrust Bearing (2nd Report, Dynamic Characteristics in Supersonic Operations and Static Characteristics in Sonic Operations)

Y. Miyake, T. Inaba, and T. Matsuoka
Osaka Univ., Suita, Osaka, 565 Japan, J. Tribology, Trans. ASME, 106 (1), pp 169-173 (Jan 1984) 8 figs, 2 refs

Key Words: Bearings, Gas bearings, Clearance effects, Damping coefficients, Stiffness coefficients

The dynamic characteristics of a newly proposed supersonic gas thrust bearing are analyzed under supersonic operations. Its static characteristics in sonic operations are also investigated. It is concluded that the load capacity, the stiffness factor, and the damping factor are increased proportionally to the supply pressure in either supersonic or sonic operation range which is determined according to the magnitude of the clearance.

84-1675

The Role of Cavitation in Whirl Instability in a Rotor Bearing, I -- The π-Film Model

J. Brindley, L. Elliott, and J.T. McKay
Univ. of Leeds, UK, ASME Paper No. 83-WA/APM-24

Key Words: Bearings, Whirling

Dynamically loaded rotor bearings are frequently observed to perform whirling motions, in which the center of the rotor describes some sort of closed orbit. In this paper it is demonstrated by using numerical computations of whirl orbits in a simple π-film model, the role of cavitation of the lubricant in enabling fluid forces alone to drive such stable orbits for certain ranges of parameter values.

84-1676

The Role of Cavitation in Whirl Instability in a Rotor Bearing, 2 -- Effect of Oil Inlet Position and Supply Pressure

J. Brindley, L. Elliott, and J.T. McKay
Univ. of Leeds, UK, ASME Paper No. 83-WA/APM-25

Key Words: Bearings, Whirling, Cavity effect

Whirl orbits have been calculated for a cavitated rotor bearing in which the cavity is assumed to form at an oil inlet groove and occupy the region in which subambient pressure is predicted from the equations of motion. Variations in position of the inlet groove and in the oil supply pressure have a profound influence on the behavior of the journal, largely through the variations in cavity size and position that are produced.

GEARS

(Also see No. 1565)

84-1677

Study on the Effect of Tooth Fatigue on Dynamic Performance of Gear Pair (1st Report: In the Case of Induction-Hardened Chromium Molybdenum Steel Gears)

K. Fujita, A. Yoshida, S. Nakata, and K. Kominami
Okayama Univ., Tsushima, Okayama City, 700 Japan, Bull. JSME, 26 (222), pp 2272-2278 (Dec 1983) 17 figs, 5 refs

Key Words: Gears, Gear teeth, Fatigue life, Fatigue tests

In order to elucidate the failure mode, load carrying capacity and relation between tooth profile change and dynamic performance in fatigue process of a surface hardened gear, operational fatigue tests were performed using induction-hardened chromium molybdenum steel gears. The failure mode in these experiments was pitting or tooth breakage due to tooth surface fatigue except one example in which tooth breakage occurred at tooth fillet. Tooth root strain, mode in tooth stress frequency distribution, noise and vibration increased as the tooth profile was degraded.

84-1678

Gear Single Tooth Bending Fatigue Test

R.W. Buenneke, M.B. Slane, C.R. Dunham, M.P. Semenek, M.M. Shea, and J.E. Tripp

Caterpillar Tractor Co., East Peoria, IL, SAE Paper No. 821042

Key Words: Gears, Fatigue tests, Testing techniques

A single tooth bending fatigue (STBF) technique for testing factors which could affect the fatigue life of gears has been developed. The test fixture and testing technique described in this paper were developed because of the large variations in test procedure and specimen design used throughout the industry. These variations cause difficulty in determining relative importance of metallurgical factors on fatigue life of hardened gears. Four companies participated in a round robin testing program using the identically designed fixtures to show how reproducible and sensitive the technique is to metallurigcal factors affecting fatigue life of gears.

84-1679

Improvement on the Fatigue Strength of Case Hardened Gears by a New Heat Treatment Process

K. Nakamura, K. Mihara, Y. Kibayashi, and T. Naito
Technical Research Ctr., Komatsu Ltd., SAE Paper No. 821102 (SP-522)

Key Words: Gears, Fatigue life

Retained austenite in the surface of carburized or carbonitrided steel improves the pitting resistance of the steel under rolling contact, although some deteriorative effect on the bending fatigue is reported. The aim of this study is to make clear the influence of retained austenite content on the pitting and on the bending fatigue, and also to develop a heat treating process which enables quantitative control of retained austenite on the surface of gears.

84-1680

Prediction of Fatigue Life of Spiral Teeth through Analysis of Finite Elements and Experimental Checks

D. Barbiero, A. Garro, and F. Rossi
Fiat Auto S.p.A., Direzione Tecnica, Sviluppo Progetti, SAE Paper No. 820781

Key Words: Gear teeth, Gear boxes, Fatigue life, Finite element technique

During initial gearbox design, the present trend is to use gears with little diametral pitch and less valuable steel; first for noise problems and then for economical and political reasons connected with the strategical availability of some alloy materials. These reasons brought the teeth limit of fatigue to minimum required values for gearbox endurance and new methods of calculation were developed more and more sophisticated than old ones. The paper describes the theoretical approach to the stress calculation and discusses the possibility of comparing the calculated data with the fatigue tests and the related actual performances of the gears in the case of different heat treating or surface finishing conditions.

84-1681

A Basic Approach to Gearbox Noise Prediction

L.D. Mitchell and J.W. Daws
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA, SAE Paper No. 821065 (SP-523)

Key Words: Gear boxes, Noise prediction

An overview of a strategy for the prediction of noise from industrial gearboxes is provided. A review of the history of predictive noise control in gearboxes is given. This paper details the computational strategy for the determination of the dynamic response of the internal gearbox components. The approaches presented here are significant departures from those carried out in the past.

84-1682

Simulation on Rotational Vibration of Spur Gears

K. Umezawa, T. Sato, and J. Ishikawa
Tokyo Inst. of Tech., Res. Lab. of Precision Machinery and Electronics, Nagatsuta, Midori-ku, Yokohama, Japan, Bull. JSME, 27 (223), pp 102-109 (Jan 1984) 12 figs, 19 refs

Key Words: Gears, Gear teeth, Spur gears, Vibration analysis, Stiffness effects, Geometric imperfection effects

This paper introduces a developed simulator on rotational vibration and strain at the root of a tooth on a power transmission spur gear. The simulator solves a differential equation with one degree of freedom in consideration of the behavior of the stiffness around tooth tip meshing. The stiffness function is discussed and determined with static and dynamic meshing tests under load. The errors of the gears are put into the simulator with a newly developed automatic gear accuracy measuring instrument.

COUPLINGS

84-1683

Torsional Vibrations of Reciprocating Engine Machinery with Nonlinear Couplings (Drehschwingungen in Kolbenmaschinenanlagen mit nichtlinearen Kupplungen)

V. Zoul

Forschungsinstitut f. Diesel lokomotiven, Prague Czechoslovakia, Maschinenbautechnik, 33 (2), pp 57-60 (1984) 7 figs, 10 refs

(In German)

Key Words: Couplings, Torsional vibration

Modern drive units are often equipped with highly elastic couplings. As a result of the ever present preload, additional problems are caused when asymptotical methods are used for the calculation of torsional vibrations. This article takes into consideration the effect of preload and vibration amplitude in the analysis of nonlinear couplings.

FASTENERS

(Also see Nos. 1582, 1800, 1801)

84-1684

Vibrations of Bonded Beams with a Single Lap Adhesive Joint

H. Saito and H. Tani

Tohoku Univ., Sendai, Japan, J. Sound Vib., 92 (2), pp 299-309 (Jan 22, 1984) 8 figs

Key Words: Joints (junctions), Adhesives, Beams, Cantilever beams, Bonded structures, Natural frequencies, Loss factor

The natural frequencies and loss factors of the coupled longitudinal and flexural vibrations of a system consisting of a pair of parallel and identical elastic cantilevers which are lap-jointed by viscoelastic material over a length a_c from their free ends are investigated. A complete set of equations of motion and boundary conditions governing the vibration of the system are derived. The solution of these equations, subject to satisfying the boundary conditions, yields the desired natural frequencies and associated composite loss factors.

84-1685

Ultrasonic Testing of Austenitic Stainless Steel Welds

S. Nishino, Y. Hida, M. Yamamoto, T. Ando, and T. Shirai

Mitsubishi Heavy Industries, Ltd., Tokyo, Japan, Rept. No. MTB-152, 9 pp (May 1982)

DE83703010

Key Words: Joints (junctions), Welded joints, Testing techniques, Ultrasonic techniques

Ultrasonic testing of austenitic stainless steel welds is considered difficult because of the high noise level and remarkable attenuation of ultrasonic waves. To improve flaw detectability in this kind of steel, various inspection techniques are studied.

84-1686

Characteristics of Threaded Joints in Ultrasonic Vibrating System

H. Kumehara, K. Morimura, K. Maruyama, and I. Yoshimoto

Gunma Univ., Kiryu, Japan, Bull. JSME, 27 (223), pp 117-123 (Jan 1984) 13 figs, 7 refs

Key Words: Joints (junctions), Ultrasonic vibration

In order to develop the most suitable design method of the threaded joints in an ultrasonic vibration system, the effects of dimensions of the threaded joint, form accuracy of bearing surface and tightening force on the characteristics of transmitting ultrasonic vibration are investigated experimentally and theoretically.

SEALS

84-1687

Dynamic Analysis of Rotary Combustion Engine Seals

J. Knoll, C.R. Vilmann, H.J. Schock, and R.P. Stumpf

NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. E-1902, NASA-TM-83536, 15 pp (1984)

N84-14519

Key Words: Seals, Combustion engines, Rotating machinery

Real time work cell pressures are incorporated into a dynamic analysis of the gas sealing grid in rotary combustion engines. The analysis which utilizes only first principal concepts accounts for apex seal separation from the trochoidal bore, apex seal shifting between the sides of its restraining channel, and apex seal rotation within the restraining channel. The results predict that apex seals do separate from the trochoidal bore and shift between the sides of their channels. The results also show that these two motions are regularly initiated by a seal rotation. The predicted motion of the apex seals compares favorably with experimental results. Frictional losses associated with the sealing grid are also calculated and compare well with measurements obtained in a similar engine. A comparison of frictional losses when using steel and carbon apex seals has also been made as well as friction losses for single and dual side sealing.

84-1688

Turbulent Flow Annular Pump Seals -- A Literature Review

L. E. Barrett

Univ. of Virginia, Charlottesville, VA 22901, Shock Vib. Dig., 16 (2), pp 3-13 (Feb 1984) 2 figs, 55 refs

Key Words: Seals, Pumps, Nuclear reactors, Reviews

This paper presents a review of the literature on turbulent flow annular seals including both theoretical and experimental work. Emphasis is placed on the application of these seals to main coolant pumps used in nuclear reactor facilities. A numerical example for calculating the dynamic force coefficients for rotor-dynamic response is presented together with design considerations relevant to main coolant pump applications.

84-1689

Dynamics of Two-Phase Face Seals

R.M. Beeler and W.F. Hughes

Carnegie-Mellon Univ., Pittsburgh, PA 15213, ASLE, Trans., 27 (2), pp 146-153 (Apr 1984) 15 figs, 6 refs

Key Words: Seals, Phase effects

The effects of phase change on load support is studied analytically for parallel and tapered face seals. An adiabatic model for low Reynolds number flow is considered. The descriptive fluid equations are integrated numerically to give opening force due to fluid film pressure. Loci of steady-state solutions are plotted for water to give curves of load support as a function of film thickness. A quasi-steady transient analysis is made for axial excursions of the seal rings.

STRUCTURAL COMPONENTS

STRINGS AND ROPES

84-1690

Iterative Solution of a Non-Linear Boundary Value Problem for a Rotating Spring

C.D. Luning and W.L. Perry

Sam Houston State Univ., Huntsville, TX 77340, Intl. J. Nonlin. Mech., 19 (1), pp 83-92 (1984) 1 fig, 2 tables, 8 refs

Key Words: Strings, Rotating structures, Equations of motions, Boundary value problems

The problem of determining the motion of a rotating inextensible string of length l, free at one end and fixed at the other can, under certain assumptions, be treated by solving a nonlinear boundary value problem. In this paper two Picard-type iterative schemes are constructed and the sequences generated are proved to converge to a positive solution of that nonlinear boundary value problem.

84-1691

Free Vibrations of a Loaded Rubber String

M.F. Beatty and A.C. Chow

Univ. of Kentucky, Lexington, KY 40506, Intl. J. Nonlin. Mech., 19 (1), pp 69-82 (1984) 5 figs, 9 refs

Key Words: Strings, Elastomers, Free vibration

The problem of the finite amplitude, free vertical oscillatory motion of a mass attached to a neo-Hookean rubberlike string is solved exactly in terms of elementary functions and the Heuman lambda function, which is related to the elliptic integral of the third kind. Hence, the period of the oscillations for the various possible motions may be computed from tables of values of the complete lambda function.

CABLES

84-1692

Vibration of Overhead Transmission Lines IV

R.N. Dubey and C. Sahay

Univ. of Waterloo, Waterloo, Ontario, Canada, Shock Vib. Dig., 15 (12), pp 11-15 (Dec 1983) 32 refs

Key Words: Transmission lines, Wind-induced excitation, Galloping, Damping effects

This review describes recent literature published in various areas related to vibration of overhead transmission lines. *Topics include wind loading, aeolian vibration, wake-induced* oscillation, galloping, and damping.

84-1693

Finite Deformation Analysis of Cable Networks

A. Chisalita

Polytechnical Inst. of Cluj-Napoca, Romania, ASCE J. Engrg. Mech., 110 (2), pp 207-223 (Feb 1984) 4 figs, 3 tables, 24 refs

Key Words: Cables, Finite deformation theory, Natural frequencies, Mode shapes

A finite deformation formulation for dynamic analysis of cable nets is presented. Lagrangian coordinates and Piola-Kirchhoff stresses are used and elasto-plastic material behavior is considered. Under assumption of straight cable elements and a displacement field varying linearly along the element, global equations of motion are established by referring the displacements to an initial configuration. These equations are linearized for iterative computation of the equilibrium configuration and for determining the eigenfrequencies and mode shapes of the linear vibration of the net about its equilibrium configuration. This analysis is performed by means of a computer program that can analyze nets anchored in fixed points.

84-1694

Planar Non-Linear Free Vibrations of an Elastic Cable

A. Luongo, G. Rega, and F. Vestroni

Istituto di Scienza delle Costruzioni, Universita di Roma Via Eudossiana 18, 00184, Roma, Italy, Intl. J. Nonlin. Mech., 19 (1), pp 39-52 (1984) 7 figs, 1 table, 15 refs

Key Words: Cables, Equations of motion, Nonlinear theories

Continuum nonlinear equations of free motion of a heavy elastic cable about a deformed initial configuration are developed. Referring to an assumed mode technique one ordinary equation for the cable planar motion is obtained via a Galerkin procedure, an approximate solution of which is pursued through a perturbation method. Suitable nondimensional results are presented for the vibrations in the first symmetric mode with different values of the cable properties.

84-1695

Linear Dynamics of Cables and Chains

M.S. Triantafyllou

Massachusetts Inst. of Tech., Cambridge, MA 02139, Shock Vib. Dig., 16 (3), pp 9-17 (Mar 1984) 5 figs, 42 refs

Key Words: Cables, Chains, Reviews

This paper is a review of cable dynamics. A historical background is followed by sections containing literature reviews of the formulation of the problem and of linear dynamics. Effects of elasticity on the linear dynamics of an elastic cable hanging between two points at the same level are stressed.

BARS AND RODS

(Also see No. 1703)

84-1696

Wave Propagation in an Infinite Long Bar of Arbitrary Cross Section and with a Circular Cylindrical Cavity

K. Nagaya and T. Watanabe

Gunma Univ., Tejin-Cho-Kiryu, Gunma 376, Japan, J. Acoust. Soc. Amer., 75 (3), pp 834-841 (Mar 1984) 3 figs, 4 tables, 26 refs

Key Words: Bars, Cavity-containing media, Wave propagation, Solid rocket propellants

This paper presents a method for solving wave propagation problems of an infinite bar of arbitrary cross section with a circular cylindrical cavity. In the analysis the exact solution of the wave equations based on the three-dimensional theory of elasticity which satisfies the boundary conditions of the inner circular cylindrical cavity has been utilized. The boundary conditions of the outer arbitrarily shaped surface of the bar are satisfied by use of the Fourier expansion collocation method. The analysis derives the frequency equation for determining the phase velocities of the bar of arbitrary cross section with the cavity. As an example numerical calculations have been carried out for an elliptical cross-section bar with a circular cylindrical cavity.

84-1697

Stability of Follower-Force Rods with Weight

H.H.E. Leipholz and R. Piche

Univ. of Waterloo, Waterloo, Ontario, Canada, ASCE J. Engrg. Mech., 110 (3), pp 367-379 (Mar 1984) 6 figs, 14 refs

Key Words: Rods, Follower forces, Flutter, Missiles

The effect of follower forces and weight on the stability of elastic rods is studied using the 2-mode Galerkin method. Stability bounderies are presented to show how various combinations of the loads lead to divergence or flutter instability. Results are presented for pinned-pinned rods, clamped-free rods and free-free rods. The free-free rod corresponds to a flexible missile with distributed follower forces due to drag and weight-like forces due to thrust.

BEAMS

(Also see Nos. 1684, 1722)

84-1698

Structural Response of RC-Members in Case of Impulsive Loading Failure Analysis in Bending and Shear

C. van der Veen and J. Blaauwendraad

Delft Univ. of Tech., Delft, Holland, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol 1, pp 182-187, 8 figs, 7 refs

Key Words: Beams, Impact excitation, Reinforced concrete, Failure analysis

Beams and one-way slabs subjected to impulsive loading are analyzed with the aid of a numerical model, which is kept as simple as possible, and which is sufficiently powerful to simulate real beam response. Therefore the beam is schematized as a system of rigid sections and elasto-plastic hinges which can account for hysteresis. The equations which hold for this discrete model are presented. They are solved by use of the systems dynamics language Dynamo.

84-1699

Unilateral Contact, Dynamic Analysis of Beams by a Time-Stepping, Quadratic Programming Procedure

E. Mitsopoulou

Dept. of Civil Engrg., School of Tech., Aristotle Univ. of Thessaloniki-Greece, Meccanica, 18 (4), pp 254-265 (Dec 1983) 10 figs, 23 refs

Key Words: Beams, Nonlinear programming

This paper discusses a method for the dynamic analysis of a slender beam, undergoing small deformations and contrasted without friction by a supporting profile. The relevant contact-impact (unilateral constrained) problem is studied, with reference to a discrete model in space and time, after its formulation as a quadratic programming problem with sign constraints only. The contact-impact problem for a rigid supporting profile is first solved, and subsequently the contact problem for an elastic profile.

84-1700

Ritz Finite Element Approach to Nonlinear Vibrations of Beams

B.S. Sarma and T.K. Varadan

Defence Res. and Dev. Lab., Hyderabad, India, Intl. J. Numer. Methods Engrg., 20 (2), pp 353-367 (Feb 1984) 1 fig, 8 tables, 16 refs

Key Words: Beams, Flexural vibration, Finite element technique, Ritz method

A Ritz finite element approach is used here to study the large amplitude free flexural vibrations of beams with immovable ends. The formulation is based on Lagrange's equation of motion with the definition of the time function at an instant corresponding to the point of reversal. The element displacement vector is chosen as a combination of inplane and transverse displacements. The nonlinear stiffness is written as a combination of the bending-membrane interaction and bending stiffness. The solution for nonlinear equations is sought by using an algorithm – the direct iteration technique – suitably modified for eigenvalue problems. Convergence is checked using the displacement norms on eigen-modes, and frequency norms for eigenvalues.

84-1701

Free Vibration Analysis with Beam Models Which Include Bending Warping, Torsion Warping and Anticlastic Bending Effects

M.S. Ewing

Ph.D. Thesis, Ohio State Univ., 138 pp (1983) DA8400194

Key Words: Beams, Free vibration, Cantilever beams, Transverse shear deformation effects, Rotatory inertia effects

Vibration models for straight, constant cross-section, non-rotating cantilever beams are considered with particular regard for those models which include shear deformation and rotary inertia. A review of existing models and articles bearing on improvements to these models is given. Three new models are introduced: a combined bending and torsion model for beams of arbitrary cross-section which includes torsion warping effects; a symmetric bending model which includes bending warping effects; and a symmetric bending model which includes bending warping and anticlastic bending effects.

84-1702

Coupled Flexural-Torsional Vibration of Beams in the Presence of Static Axial Loads and End Moments

A. Joshi and S. Suryanarayan

India Inst. of Tech., Bombay, India, J. Sound Vib., 92 (4), pp 583-589 (Feb 22, 1984) 5 figs, 4 refs

Key Words: Beams, Coupled response, Flexural vibration, Torsion vibration

The problem of coupled flexural-torsional vibration of a deep rectangular beam in the presence of a static axial load and an end moment is studied. Closed form analytical solutions are obtained for simply supported boundary conditions. Numerical results are obtained for the coupled frequencies and mode shapes (in terms of the location of axes of rotation of the cross-section) for different values of the load and the geometry parameters.

84-1703

A Note on the Acoustic Radiation from Point-Forced Elastic Beams

R.F. Keltie

North Carolina State Univ., Raleigh, NC 27650, J. Sound Vib., 92 (2), pp 253-260 (Jan 22, 1984) 3 figs, 9 refs

Key Words: Bars, Beams, Elastic properties, Damped structures, Sound waves, Wave radiation, Point source excitation

An exact expression for the acoustic power radiated by a point-excited damped bar is derived through direct integration of the theoretical surface acoustic intensity distribution. The effects of structural damping and wavenumber ratio on the power are presented. Expressions are obtained for the contributions to the total acoustic power arising from the propagating portion of the vibratory response and the non-propagating or flexural near field portion of the vibratory response, separately.

84-1704

The Response of a Beam to a Transient Pressure Wave Load

A. Kunow-Baumhauer

Mannesmann Anlagenbau AG, Theodorstrasse 90, 4000 Düsseldorf 30, W. Germany, J. Sound Vib., 92 (4), pp 491-506 (Feb 22, 1984) 9 figs, 3 tables, 9 refs

Key Words: Beams, Moving loads, Flexural waves, Wave propagation, Bernoulli-Euler method, Timoshenko theory

The dynamic behavior of beam structures under pressure waves is investigated. The propagation of the bending waves under a moving single load is studied for three types of beam: a Bernoulli-Euler beam, a beam with shear deflection and a Timoshenko beam. The responses of the Bernoulli-Euler and the Timoshenko beam are studied under moving pressure wave excitation. The results are presented as dynamic amplification factors. The influence of the load parameters (load shape, propagation speed, pressure wave duration, etc.) and the beam parameters (slenderness, damping, etc.) is discussed.

84-1705

Influence of the Order of Polynomial on the Convergence in Ritz Finite Element Formulation to Nonlinear Vibrations of Beams

B.S. Sarma, G. Prathap, and T.K. Varadan

Defence Res. and Dev. Lab., Hyderabad, India, Computers Struc., 18 (4), pp 667-671 (1984) 3 tables, 6 refs

Key Words: Beams, Nonlinear vibration, Finite element technique, Ritz method

The influence of the order of inplane polynomial on the convergence of solution, when a Ritz finite element formulation is used to study nonlinear vibratic s of beams, is investigated. Three types of polynomial distributions for the inplane displacement u are considered while the polynomial distribution for transverse displacement w is always retained as cubic. A hinged-hinged beam on immovable ends with different discretization is chosen as an example for the convergence study on the nonlinear hardening parameter.

84-1706

Engineering Approximation of Beam Flutter

L.E. Ericsson

Lockheed Missiles & Space Co., Inc., Sunnyvale, CA, J. Spacecraft Rockets, 21 (1), pp 6-8 (Jan/Feb 1984) 4 figs, 2 refs

Key Words: Beams, Flutter

A technique is presented for rapid construction of approximate flutter boundaries for a beam without access to detailed structural information. The method is a useful preliminary design tool which permits easy evaluation of the effects of design changes thereby facilitating finding the means to eliminate aeroelastic instability, should it occur. An example is presented from a recent analysis of the dynamic aeroelastic stability of space shuttle protuberances.

84-1707

Improved Finite-Difference Analysis of Uncoupled Vibrations of Tapered Cantilever Beams

K.B. Subrahmanyam and K.R.V. Kaza

NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. E-1828, NASA-TM-83495, 39 pp (Sept 1983) N84-13610

Key Words: Beams, Cantilever beams, Variable cross section, Natural frequencies, Mode shapes

An improved finite difference procedure for determining the natural frequencies and mode shapes of tapered cantilever beams undergoing uncoupled vibrations is presented. Boundary conditions are derived in the form of simple recursive relations involving the second order central differences. Results obtained by using the conventional first order central differences and the present second order central differences are compared, and it is observed that the present second order scheme is more efficient than the conventional approach.

84-1708

Coupled Thermoelastic Vibrations of a Timoshenko Beam

C.V. Massalas and V.K. Kalpakidis

Dept. of Mechanics, Univ. of Ioannina, Ioannina, Greece, Intl. J. Engrg. Sci., 22 (4), pp 459-465 (1984) 4 figs, 12 refs

Key Words: Beams, Timoshenko theory, Temperature effects

The dynamic behavior of a Timoshenko beam subjected to a step heat flux to the surface $z = +h/2$ at time $t = 0^+$ is studied. The mathematical analysis is based on integral transforms, the Muller's method of solving algebraic equations and the Heaviside expansion theorem. From the numerical results presented the effect of inertia and that of the coupling between temperature and strain fields on the dynamic behavior of the beam as well as the distribution of the temperature fields with time is shown.

84-1709

Acoustic Radiation from a Viscoelastic Beam Impacted by a Steel Sphere

M. Sakata, M. Horii, and T. Kimura

Tokyo Inst. of Tech., Meguro-ku, Tokyo 152, Japan, J. Sound Vib., 92 (1), pp 67-81 (Jan 8, 1984) 12 figs, 3 tables, 12 refs

Key Words: Beams, Viscoelastic properties, Impact response, Flexural vibration

The acoustic radiation from a viscoelastic beam impacted by a steel sphere is studied theoretically and experimentally. Transverse vibrations of free-free viscoelastic beams are analyzed by employing the modal analysis technique and an approximate method, with the Hertz theory used to evaluate impact forces. The wave equation was solved to determine the acoustic pressure radiated from impacted beams of circular and elliptical cross-sections. The theoretical predictions are compared with the experimental results for the radiation from PMMA beams of circular and rectangular cross-sections.

84-1710

Vibration Response of Geometrically Nonlinear Elastic Beams to Pulse and Impact Loading

H. Liebowitz

School of Engrg. and Applied Science, George Washington Univ., Washington, DC, Rept. No. NASA-CR-174495, 33 pp (Oct 7, 1983) N84-12527

Key Wrods: Beams, Pulse excitation, Impact excitation, Vibration response

The governing equations for the geometrically nonlinear deformation of elastic beams subjected to dynamic bending loads are developed and solved for various initial conditions. Of primary interest is the response to pulse loading and simulated impact. Both transient and several cycle solutions are generated for the free vibration response to pulse loading. The results obtained are compared to a first mode analysis approximation. A model is developed to simulate impact loading by the distribution of additional mass to the elastic system and subjecting it to a velocity pulse.

CYLINDERS

84-1711

Limit Amplitudes of Galloping Bluff Cylinders

L.E. Ericsson

Lockheed Missiles & Space Co., Inc., Sunnyvale, CA, AIAA J., 22 (4), pp 493-497 (Apr 1984) 11 figs, 20 refs

Key Words: Cylinders, Galloping

An analysis is presented for the galloping in a single degree of freedom of bluff cross sections. The limit cycle oscillation phenomenon is studied in particular, and the maximum possible galloping amplitude of an arbitrary cross section is derived. The theoretical results are found to be in good agreement with available experimental results.

84-1712

Dynamical Response of Bar-Fluid-Shell System Simulating Hydraulic Cylinder Subjected to Arbitrary Axial Excitation

L. Tomski and S. Kukla

Inst. of Mechanics and Machine Design, Technical Univ. of Czestochowa, 42-200 Czestochowa, Poland, J. Sound Vib., 92 (2), pp 273-284 (Jan 22, 1984) 7 figs, 16 refs

Key Words: Cylinders, Hydraulic systems, Axial excitation, Fluid-induced excitation, Laplace transformation, Fourier transformation

The dynamics of a bar-fluid-shell system simulating a hydraulic cylinder subjected to arbitrary axial excitation is studied analytically. The techniques of the Laplace transform and the finite cosine Fourier transform are employed. The solution expressed in the Laplace transform domain is obtained. Analytical solutions for the forced harmonic vibrations of the system are given and the transformed solution for mass impact is inverted numerically for large time.

COLUMNS

84-1713

Stability, Vibration and Passive Damping of Partially Restrained Imperfect Columns

Z. Razzaq, R.T. Voland, H.G. Bush, and M.M. Mikulas, Jr.

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-85697, 38 pp (Oct 1983)

N84-13608

Key Words: Columns, Natural frequencies, Damping

A theoretical and experimental study of slender tubular columns for possible use in space structures is conducted in the presence of partial rotational end restraints. Explicit formulas are derived for computing the buckling load and the lowest natural frequency of perfectly straight uniform elastic members with rotational end restraints possessing linear moment-rotation characteristics. An exact solution in the form of a transcendental equation, and a numerical solution using second-order finite-differences are also presented.

84-1714

Transient Flexural Vibrations of a Timoshenko Column Supported by an Elastic Half-Space

H. Wada

Tohoku Univ., Sendai 980, Japan, Earthquake Engrg. Struc. Dynam., 12 (2), pp 169-179 (Mar/Apr 1984) 7 figs, 5 refs

Key Words: Columns, Timoshenko theory, Elastic half-space, Flexural vibration

Transient flexural vibrations of an elastic column supported by an elastic half-space are investigated analytically under the condition that an arbitrarily shaped free-field lateral acceleration is given as an input. Applying the Timoshenko theory to the column and making use of Laplace transformations with respect to time and numerical inverse Laplace transformations, the time histories of the column free end acceleration are presented.

MEMBRANES, FILMS, AND WEBS

84-1715

Acoustic Scattering by Baffled Membranes

G.A. Kriegsmann, A. Norris, and E.L. Reiss

The Technological Inst., Northwestern Univ., Evanston, IL 60201, J. Acoust. Soc. Amer., 75 (3), pp 685-694 (Mar 1984) 8 figs, 10 refs

Key Words: Membranes (structural members), Sound waves, Wave scattering

A flexible membrane is set in an infinite plane baffle. The plane separates an acoustic field from a vacuum. A time harmonic wave is incident from the fluid on the membrane. When the frequency of the incident wave is not close to an in-vacuo resonant frequency of the membrane, the reaction of the fluid on the membrane is small. However, near a resonant frequency the fluid-membrane coupling is significant. The method of matched asymptotic expansions is used to obtain an asymptotic expansion of the scattered field. It is uniformly valid in the incident frequency.

PLATES

(Also see Nos. 1568, 1736, 1741)

84-1716

In-Plane Accelerations and Forces on Frequency Changes in Doubly Rotated Quartz Plates

P.C.Y. Lee and Kuang-Ming Wu

Princeton Univ., Princeton, NJ 08544, J. Acoust. Soc. Amer., 75 (4), pp 1105-1117 (Apr 1984) 17 figs, 17 refs

Key Words: Plates, Quartz, Resonant frequencies

Two-dimensional equations of motion of doubly rotated quartz plates for the thickness-shear, flexure, and extensional vibrations under in-plane initial stresses are employed to predict changes in the fundamental thickness-shear frequencies due to initial stresses. Two types of initial stresses are considered: stresses due to a pair of diametral forces, and stresses due to steady accelerations for a three-point "T"-shaped mount and a four point "+"-shaped mount configuration. Force sensitivity and acceleration sensitivity coefficients are computed and compared with experimental data and existing computed results.

84-1717

Nonlinear Dynamics and Control of a Vibrating Rectangular Plate

J.V. Shebalin

Kentron International Inc., Hampton, VA, Rept. No. NASA-CR-172215, 41 pp (Oct 1983)
N84-12528

Key Words: Plates, Rectangular plates, Fourier transformation

The von Karman equations of nonlinear elasticity are solved for the case of a vibrating rectangular plate by means of a Fourier spectral transform method. The amplification of a particular Fourier mode by nonlinear transfer of energy is demonstrated for this conservative system. The multi-mode system is reduced to a minimal (two mode) system, retaining the qualitative features of the multi-mode system. The effect of a modal control law on the dynamics of this minimal nonlinear elastic system is examined.

84-1718

Large Amplitude Free Vibrations of a Square Plate of Variable Thickness

S.K. Chaudhuri

Acharya B.N. Seal College, Cooch-Behar, W. Bengal, India, J. Sound Vib., 92 (1), pp 143-147 (Jan 8, 1984) 1 fig, 1 table, 12 refs

Key Words: Plates, Rectangular plates, Variable cross section, Free vibration, Large amplitudes

The large amplitude free vibrations of a square plate of exponentially varying thickness are investigated by using von Kármán's equations expressed in terms of displacement components. The numerical results are given in tabular form.

84-1719

Effects of Geometric Imperfections on Vibrations of Biaxially Compressed Rectangular Flat Plates

D. Hui and W.W. Leissa

Ohio State Univ., Columbus, OH, ASME Paper No. 83-WA/APM-20

Key Words: Plates, Rectangular plates, Geometric imperfection effects, Vibration frequencies

This paper deals with the effects of geometric imperfections on the vibration frequencies of simply supported flat plates under in-plane uniaxial or biaxial compression. The analysis is based on a solution of the nonlinear von Karman equations for finite deflections, incorporating the influence of an initial geometric imperfection.

84-1720

Response of a Plate to a Transient Pressure Wave Load

A. Kunow-Baumhauer

Mannesmann Anlagenbau AG, Theodorstrasse 90, 4000 Düsseldorf 30, W. Germany, J. Sound Vib., 92 (4), pp 507-515 (Feb 22, 1984) 6 figs, 3 tables, 9 refs

Key Words: Plates, Moving loads, Flexural waves, Wave propagation

The dynamical behavior of a Kirchhoff plate under a moving pressure wave is investigated. The results are presented as dynamic amplification factors. The influence of the load parameters (propagation speed, pressure wave duration) and the plate parameters (slenderness, aspect ratio, damping, etc.) is discussed. Results for two examples are presented.

84-1721

Frequency Determination Techniques for Cantilevered Plates with Bending-Torsion Coupling

D.W. Jensen and E.F. Crawley

Massachusetts Inst. of Tech., Cambridge, MA, AIAA J., 22 (3), pp 415-419 (Mar 1984) 6 figs, 3 tables, 9 refs

Key Words: Plates, Flexural vibration, Torsional vibration, Coupled response, Natural frequencies, Mode shapes

Various techniques for solution of the variational statement governing vibration of cantilevered composite plates are compared. The partial Ritz (Kantorovich) method assumes mode shapes only in the chordwise direction and reduces the problem to a set of ordinary differential equations. The important nondimensional parameters for cantilevered plates with bending-torsion coupling then are identified easily, including two that express the relative contribution of the warping stiffness to torsional vibration (β_{66}) and chordwise vibration (β_{22}).

84-1722

Effect of a Concentrated Mass on Large Amplitude, Free Flexural Vibrations of Elastic Plates and Beams

R.H. Gutiérrez and P.A.A. Laura

Inst. of Appl. Mechanics, 8111 Puerto Belgrano Naval Base, Argentina, Appl. Acoust., 17 (2), pp 135-151 (1984) 3 figs, 6 tables, 6 refs

Key Words: Plates, Beams, Flexural vibration, Approximation methods

This paper presents an approximate solution to the title problem for the following situations: supported and clamped rectangular plates, circular plates with edges elastically restrained against rotation, and beams with ends flexibly attached. The approach is quite simple and it is shown that the engineering accuracy achieved is satisfactory from the point of view of the determination of fundamental frequencies in a wide variety of structural elements commonly used in transducer design and aerospace and naval applications.

84-1723

A Multiple-Mode Approach to Large-Amplitude Vibration of Moderately Thick Elliptical Plates

M. Sathyamoorthy and M.E. Prasad

Clarkson College of Tech., Potsdam, NY 13676, J. Appl. Mech., Trans. ASME, 51 (1), pp 153-158 (Mar 1984) 5 figs, 6 tables, 18 refs

Key Words: Plates, Vibration analysis, Large frequencies, Transverse shear deformation effects, Rotatory inertia effects

Based on a multiple-mode analysis, solutions to the nonlinear equations of motion are presented for elliptical plates in terms of variations of nonlinear periods with amplitudes of vibration. The governing equations are written in terms of lateral displacement w and stress function F and the effects of transverse shear deformation and rotatory inertia are incorporated into these equations. For the multiple-mode approach considered in this paper, an exact solution to the stress function is determined. Effects of geometric nonlinearity, shear deformation, rotatory inertia, plate geometry, and modal interaction on the vibration behaviors of elliptical plates are investigated in detail.

84-1724

Use of LaGrange Multipliers with Polynomial Series for Dynamic Analysis of Constrained Plates. Part 1: Polynomial Series

E. Goldfracht and G. Rosenhouse

Technion-Israel Inst. of Tech., 32000 Haifa, Israel, J. Sound Vib., 92 (1), pp 83-93 (Jan 8, 1984) 3 figs, 3 tables, 24 refs

Key Words: Plates, Stiffened plates

A theory for prediction of the dynamic response of a constrained plate is presented. The boundaries of the plate may

be partially fixed, its dynamic loading is due to elastically mounted vibrating machines and its constraints include beam-like stiffeners. The theory yields the eigenvalues and modal shapes of the plate and stiffeners which compromise the system. The solution is based on Galerkin's method combined with use of special polynomial series presented by Kantorovich and Krylov.

84-1725

Use of LaGrange Multipliers with Polynomial Series for Dynamic Analysis of Constrained Plates. Part II: LaGrange Multipliers

G. Rosenhouse and E. Goldfracht
Technion-Israel Inst. of Tech., 32000 Haifa, Israel, J. Sound Vib., 92 (1), pp 95-106 (Jan 8, 1984) 4 figs, 2 tables, 14 refs

Key Words: Plates, Stiffened plates

The eigenvalues, modal shapes and response of constrained plates, loaded by vibrating single degree of freedom machinery, are derived. The results for the complete system are obtained by application of Lagrange equations and Lagrange multipliers. The coefficients of the solution are found with the aid of polynomial series. The variants considered are an unstiffened and a beam-stiffened plate.

84-1726

Emission of Stress Waves During Fracture

P.S. Theocaris and H.G. Georgiadis
The National Technical Univ. of Athens, 5 Heroes of Polytechnion Ave., Athens 624, Greece, J. Sound Vib., 92 (4), pp 517-528 (Feb 22, 1984) 10 figs, 1 table, 24 refs

Key Words: Plates, Fracture properties, Stress waves, Elastic waves

Emission of both longitudinal and surface (Rayleigh) waves during fracture of plates under conditions of plane stress and plane strain were studied experimentally. The non-equilibrated tensile stress in the fractured section of the plate creates an elastic wave, which travels radially along the plate at the sound speed. Moreover, the high surface deformation around the crack tip, due to the high stress concentration there, propagates as a surface wave following fracture of this zone, at the respective Rayleigh wave speed with a circular wavefront. The influence of the thickness of the plate and the type of fracture (brittle or ductile) was examined utilizing a high speed photography technique.

84-1727

A Theoretical Analysis of Transient Sound Radiation from a Clamped Circular Plate

A. Akay, M. Tokunaga, and M. Latcha
Wayne State Univ., Detroit, MI 48202, J. Appl. Mech., Trans. ASME, 51 (1), pp 41-47 (Mar 1984) 4 figs, 25 refs

Key Words: Plates, Circular plates, Sound waves, Wave propagation, Impact excitation

A theoretical analysis of transient sound radiation from a clamped circular plate is given using a pressure impulse response method. The vibration response of the plate to a transient point force is obtained. The modal pressure impulse response functions for the plate are derived from the Rayleigh surface integral and numerically convoluted with the modal acceleration response of the plate. The impulse response functions are closely related to the mode shapes and the geometry of the problem. They relate the spatial domain to the temporal domain of the pressure waves. The pressure impulse response waveforms are given for a number of plate modes and the changes in the waveforms with distance from the plate are shown. Sound radiation due to forced and free vibrations of the plate are discussed.

84-1728

Oscillatory Instabilities Generated in a Double-Pin and Disc Undamped System: A Mechanism of Disc-Brake Squeal

S.W.E. Earles and M.N.M. Badi
King's College, Strand, London, WC2, UK, IMechE, Proc., 198 (4), pp 43-50 (1984) 12 figs, 6 refs

Key Words: Brakes (motion arresters), Noise generation, Disks

A dynamic analysis is presented of a double-pin and disc system, which is undamped and has linear characteristics. A self-induced oscillatory motion is generated which can become unstable for certain combinations of the system's parameters. Distinct changes from a quiet to a noisy state are observed on an experimental system; the noisy state regions having a good correlation with the instability regions shown theoretically. It is concluded that a kinematic constraint or geometrically induced class of instability exists theoretically which essentially describes the mechanism of squeal noise generation in disc-brakes.

84-1729

Interpretation of Rubbing Noise Radiated from a Pin-on-Disc Configuration

C.-H. Wang and A. Soom

State Univ. of New York at Buffalo, ASME Paper No. 83-WA/NCA-4

Key Words: Disks, Contact vibration, Noise generation

The sound radiated due to rubbing action by a disc in contact with a nominally stationary pin is modeled by combining the normal force excitation at the contact with space-averaged disc and enclosure responses. The contact forces are associated with contact vibrations that are developed as surface irregularities are swept through the contact region. A relatively straightforward physical interpretation of the contributions of these effects to the radiated noise is shown to be possible.

84-1730

Efficiency of Annular Finite Elements for Flexural Vibrations of Thick Disks

P. Priolo and C. Sitzia

Inst. of Mech. Engrg., Univ. of Cagliari, Cagliari, Italy, J. Sound Vib., 92 (1), pp 21-31 (Jan 8, 1984) 4 figs, 4 tables, 11 refs

Key Words: Disks, Flexural vibration, Finite element technique, Transverse shear deformation effects, Rotatory inertia effects

The efficiency is evaluated of various semianalytical annular finite elements in predicting the vibrational modes for disks where the effect of transverse shear and rotary inertia becomes important, with reference both to the minimum number of degrees of freedom and to the minimum number of operations required to achieve a certain approximation for the exact natural frequency value. From this point of view, a new element, in which normal displacements are interpolated by cubic polynomials and rotations by parabolic polynomials along the radius, is compared with other elements described in the literature.

84-1731

Resonance Response of Thinwalled Elements of Carriage Bodies

A. Tesár and P. Tesár

Inst. of Structures and Architecture of the Slovak Academy of Sciences, Bratislava, Czechoslovakia, Strojnícky Časopis, 35 (1-2), pp 179-194 (1984) 21 figs, 5 refs

(In Slovak)

Key Words: Plates, Automobile bodies, Resonant response, Finite element technique, Transfer matrix method

The solution of dynamic response of thinwalled panels of carriage bodies is presented. Theoretical solution is based on the application of the method FETM, which is the problem-oriented combination of the finite element method with the method of transfer matrices. The derivation of transfer matrices dealing with the theory of small as well as of large deformations is indicated. The equations of motion are solved on the basis of combination of the FETM concept with the Wilson θ-method of numerical integration in time. Numerical as well as experimental verification of present theoretical solutions is performed. The real thinwalled panel of the automobil Škoda 1203 is studied. Obtained results submit comprehension of the real resonance behavior of studied thinwalled elements.

84-1732

Magnetohydrodynamic Flow Between Torsionally Oscillating Eccentric Disks

P.R. Rao

Indian Inst. of Science, Bangalore 560 012, India, Intl. J. Engrg. Sci., 22 (4), pp 393-402 (1984) 7 figs, 3 refs

Key Words: Disks, Magnetohydrodynamics

The unsteady MHD flow of an incompressible, viscous electrically conducting fluid contained between two torsionally oscillating eccentric disks is investigated. The state of uniform rotation of the central region visualized in the steady flow is absent in the case of oscillatory flow.

SHELLS

84-1733

Concentrated Edge Loads on Hyperboloidal Shells

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Structural Analysis Group, United Engineers and Constructors, Philadelphia, PA, ASCE J. Struc.

Engrg., 110 (1), pp 75-89 (Jan 1984) 12 figs, 1 table, 12 refs

Key Words: Shells, Harmonic excitation

It is shown that hyperboloid shells can be inexpensively analyzed under the action of concentrated loads using an axisymmetric program. The numerical analyses point out that a negative curvature shell under the action of a concentrated load tangent to the meridian develops important bending moments and out of plane shears as a condition for the distribution of the concentrated load throughout the shell.

84-1734

Asymmetric Modes and Associated Eigenvalues for Spherical Shells

A. V. Singh and S. Mirza

Ontario Hydro, Toronto, Ontario, Canada, ASME Paper No. 83-WA/PVP-8

Key Words: Shells, Spherical shells, Asymmetric excitation, Finite element technique, Transverse shear deformation effects, Rotatory inertia effects

Free asymmetric vibration of spherical shells with clamped and hinged boundary conditions are analyzed using FEM. Element stiffness and consistent mass matrices are derived using the improved shell theory, which takes into account the effects of shear deformation and rotary inertia.

84-1735

Efficient Finite Element Methods for Transient Nonlinear Analysis of Shells

T. Belytschko

Dept. of Civil Engrg., Northwestern Univ., Evanston, IL, Rept. No. AFOSR-TR-83-1062, 175 pp (Aug 1983)

AD-A136 044

Key Words: Shells, Finite element technique, Transient analysis, Algorithms

A finite element formulation and algorithm for the nonlinear analysis of the large deflection, materially nonlinear response of impulsively loaded shells is presented. A unique feature of this algorithm is the use of a bilinear four node quadrilateral element with single point quadrature and a simple hourglass control which is orthogonal to rigid body modes on an element level and does not compromise the consistency of the equations. The geometric nonlinearities are treated by using a corotational description wherein a coordinate system that rotates with the material is embedded at the integration point; thus the algorithm is directly applicable to anisotropic materials without any corrections for frame invariance of material property tensors. This algorithm can treat about 200 element-time-steps per CPU second on a CYBER 170/730 computer in the explicit time integration mode.

84-1736

Analysis of Circular Folded Plate Shells under Axially Symmetric Loads

Liu Kaiguo

J. Bldg. Struc., 4 (3), pp 12-19 (1983)

CSTA No. 624-83.56

Key Words: Shells, Axial excitation

The static, dynamic, and limit analysis of circular folded plate shells under axially symmetric loads are investigated. A mathematical model of static and dynamic analysis solved by finite differences and a failure pattern of limit analysis are presented.

84-1737

Flexural Axisymmetric Free Vibrations of a Spherical Dome: Exact Results and Approximate Solutions

H. Kunieda

Disaster Prevention Res. Inst., Kyoto Univ., Uji, Kyoto 611, Japan, J. Sound Vib., 92 (1), pp 1-10 (Jan 8, 1984) 4 figs, 4 tables, 13 refs

Key Words: Domes, Shells, Spherical shells, Natural frequencies, Mode shapes, Flexural vibration

Exact expressions exist for the natural frequencies and mode shapes of the axisymmetric free vibrations of a spherical shell or dome. However, they are not easily amenable to numerical calculation and there are no reference standards of natural frequencies and modes available for use in engineering. The exact solution is even less practical for analysis of response to dynamic loading. This paper provides the natural frequencies and modes for a wide range of conical angle, based on the exact solution. Compatible with these results, an approximate solution is proposed which is suitable for dynamic response analysis and which easily provides natural frequencies and modal shapes which are accurate enough for engineering purposes.

84-1738

Vibration and Stability of Orthotropic Circular Cylindrical Shells Subjected to Axial Load

G. Yamada, T. Irie, and M. Tsushima

Hokkaido Univ., Sapporo, 060 Japan, J. Acoust. Soc. Amer., 75 (3), pp 842-848 (Mar 1984) 4 figs, 4 tables, 25 refs

Key Words: Shells, Cylindrical shells, Axial excitation, Transfer matrix method, Natural frequencies, Critical loads

An analysis is presented for the vibration and stability of an orthotropic circular cylindrical shell subjected to an axial static load by use of the transfer matrix approach. The applicability of the thin-shell theory is assumed, and the governing equations of free vibration of the shell are written in a matrix differential equation by using the transfer matrix of the shell. Once the matrix has been determined by a solution to the equation, the natural frequencies and the critical loads are calculated numerically in terms of the elements of the matrix for a given set of boundary conditions at the edges. This method is applied to orthotropic circular cylindrical shells simply supported at the edges, and the effects of the length ratio, orthotropy, and axial load on the vibration and stability are studied.

84-1739

Sound Transmission through Layered Cylindrical Shells with Applied Damping Treatment

S. Narayanan and R.L. Shanbhag

Indian Inst. of Tech., Madras-600 036, India, J. Sound Vib., 92 (4), pp 541-558 (Feb 22, 1984) 9 figs, 5 tables, 23 refs

Key Words: Shells, Cylindrical shells, Sandwich structures, Sound waves, Wave transmission, Damped structures

Sound transmission through closed circular cylindrical shells with unconstrained damping treatment and sandwich shells with constrained damping treatment is considered in an acoustoelastic formulation in which the full interaction between the structural vibration and the internal cavity pressure field are taken into account. Only the axisymmetric modes of vibration of the shell are considered in an initial formulation. The structural response and the sound transmission characteristics for an external random pressure field are computed through an efficient matrix inversion procedure.

84-1740

Variational Method for Calculating the Natural Frequencies and Mode Shapes of a Cantilevered Open Cylindrical Shell

J.V. Kouri

School of Engrg., Air Force Inst. of Tech., Wright-Patterson AFB, OH, Rept. No. AFIT/GAE/AA/83-D-11, 93 pp (Dec 1983)

AD-A136 901

Key Words: Shells, Cylindrical shells, Cantilever shells, Variational methods, Natural frequencies, Mode shapes

This report develops a variational technique for the analysis of the vibration characteristics of an open cylindrical cantilevered shell. The technique is developed by modifying Reissner's principle, which normally applies to static problems, through the use of Hamilton's principle so that it applies to dynamic problems. The variational technique is first derived in general for an elastic system, and then specifically tailored to an open cylindrical cantilevered shell. The technique is implemented by first finding a general solution which satisfies the equations of motion for a cylindrical shell. A method is then formulated to use this general solution to construct a set of trial solution functions. With the variational method, the coefficients to this trial solution function are then calculated so that the function not only satisfies the equations of motion, but also the boundary conditions around the four edges of the shell.

84-1741

New Method of Analyzing Vibration of Cracked Cylindrical Shells

R. Solecki

Dept. of Mech. Engrg., Univ. of Connecticut, Storrs, CT, Rept. No. UCONN-ME-82-83-ONR-1, 72 pp (Dec 26, 1983)

AD-A136 637

Key Words: Plates, Shells, Cylindrical shells, Cracked media

The method of Fourier transformation of functions with lines of discontinuity and with built-in point singularities, is applied to analysis of vibration of cracked rectangular plates and of cracked cylindrical shells of rectangular planform. Application of the above method in conjunction with Green-Gauss Theorem leads to an infinite system of linear algebraic equations. Numerical examples include a plate with a parallel crack, a plate with a diagonal crack and a shell cracked at the apex.

84-1742

Free Vibration of a Point-Supported Circular Cylindrical Shell

T. Irie, G. Yamada, and Y. Kudoh

Hokkaido Univ., Sapporo, 060 Japan, J. Acoust. Soc. Amer., 75 (4), pp 1118-1123 (Apr 1984) 7 figs, 1 table, 9 refs

Key Words: Shells, Cylindrical shells, Natural frequencies

An analysis is presented for the free vibration of an elastically or rigidly point-supported circular cylindrical shell. For this purpose, the deflection displacements of the shell are written in a series of deflection functions of the beam. The dynamical energies of the shell are evaluated, and the frequency equation is derived by the Ritz method. For a rigidly point-supported shell, the Lagrangian multiplier method is conveniently employed. The method is applied to a cylindrical shell supported at symmetrically located four points, the natural frequencies and the mode shapes are calculated numerically, and the effects of the point supports on the vibration are studied.

RINGS

84-1743

Flexural Vibration of a Thin Rotating Ring

M. Endo, K. Hatamura, M. Sakata, and O. Taniguchi
Tokyo Inst. of Tech., Ookayama, Meguro-ku, Tokyo, Japan, J. Sound Vib., 92 (2), pp 261-272 (Jan 22, 1984) 7 figs, 2 tables, 15 refs

Key Words: Rings, Rotating structures, Flexural vibration

Flexural vibration of a thin rotating ring is investigated experimentally and theoretically. The frequencies of forward and backward flexural traveling waves are measured using strain gages. The range of rotational speeds of the ring includes frequencies comparable with that of the fundamental flexural mode of a nonrotating ring and the stability of flexural vibration is examined with consideration of the effects of the centrifugal and Coriolis forces.

84-1744

Vibration of a Three-Layered Ring on Periodic Radial Supports

E.S. Reddy and A.K. Mallik
Indian Inst. of Tech., Kanpur, India, AIAA J., 22 (4), pp 543-551 (Apr 1984) 10 figs, 17 refs

Key Words: Rings, Layered materials, Damped structures, Elastic core-containing media, Viscoelastic core-containing media, Supports, Boundary condition effects

The natural frequencies of a three-layered elastic ring on periodic radial supports are obtained by using a wave approach. Two types of support conditions are investigated. When the core is assumed to be viscoelastic, the theory of forced damped normal modes is used to obtain the resonance frequencies and the associated composite modal loss factors of the damped structure. The numerical results show the effects of the thickness ratios and the core shear modulus. The high values of the loss factor in some modes are explained with the aid of the mode shapes of the corresponding elastic ring.

PIPES AND TUBES

(Also see No. 1827)

84-1745

Correlation of Support Impact Force and Fretting-Wear for a Heat Exchanger Tube

P.L. Ko and H. Basista
Chalk River Nuclear Labs., Atomic Energy of Canada, Ltd., Chalk River, Ontario, Canada, J. Pressure Vessel Tech., Trans. ASME, 106 (1), pp 69-77 (Feb 1984) 12 figs, 2 tables, 8 refs

Key Words: Interaction: structure-support, Heat exchangers, Tubes, Fluid-induced excitation

Flow-induced tube vibration can cause dynamic interactions between a tube and its supports. Both wear information and results from vibration analyses are needed to achieve a realistic assessment of long-term tube wear. Normal and oblique impact forces at the tube supports characterize dynamic interaction between tube and tube-support, and can be correlated to the rate of fretting-wear. A statistical analysis of the force signal provides an indication of the time distribution of various force levels during a vibration cycle. Different schemes for obtaining a weighted sum of these force levels were developed to account for changes in excitation levels, tube/support clearance, and the type of tube motion.

84-1746

Response of Multipass Heat Exchangers to Sinusoidal Flow Rate Changes of Large Amplitude

I. Todo
Yokohama Natl. Univ., 165, Tokiwadai, Hodogaya-ku, Yokohama 240, Japan, Bull. JSME, 27 (223), pp 87-94 (Jan 1984) 8 figs, 5 refs

Key Words: Heat exchangers, Fluid-induced excitation, Periodic excitation

A computational method is presented for obtaining the steady-state temperature responses of 1-2 pass heat exchangers subject to sinusoidal flow rate changes of large amplitude. The frequency- and amplitude-dependent describing functions between the input sinusoidal flow rate changes and the fundamental component of the steady-state response of the outlet temperature of tube-side or shell-side fluid are also derived. Numerical examples are given and it is shown that this method can reduce computation time remarkably.

84-1747

Oscillation Modes in Single-Step Hartmann-Sprenger Tubes

M. Kawahashi, R. Bobone, and E. Brocher

Institut de Mécanique des Fluides de l'Université Aix-Marseille II, 1, rue Honnorat, 13003 Marseille, France, J. Acoust. Soc. Amer., 75 (3), pp 780-784 (Mar 1984) 9 figs, 15 refs

Key Words: Tubes, Fluid-induced excitation, Shock waves, Wave propagation

When a high velocity jet is directed toward the mouth of a tube closed at the downstream end, large, nonlinear flow oscillations may occur within the tube. Shock waves propagate up and down the tube and generate strong heating of the tube walls. The device is called a Hartmann-Sprenger tube (H-S tube). It has been proposed to strengthen the shock waves and consequently the heating effects by tapering the tube. Conical and multistepped configurations have been investigated, but also tubes having a sudden area contraction (single step). This latter geometry produces remarkable pressure and thermal heating amplification compared to a constant area tube. The paper presents theoretical and experimental results obtained for the single-step H-S tube.

84-1748

Effective Densities and Resistivities for Acoustic Propagation in Narrow Tubes

A. Craggs and J.G. Hildebrandt

Dept. of Mech. Engrg., Univ. of Alberta, Edmonton, Alberta, Canada, J. Sound Vib., 92 (3), pp 321-331 (Feb 8, 1984) 10 figs, 8 refs

Key Words: Tubes, Sound waves, Wave propagation, Finite element technique

A finite element method is used to determine the velocity profiles and boundary shear forces for sound propagation in narrow tubes of various sections. The slit, circle, triangle, square, rectangle and hexagon sections are considered and the results are shown. From the profiles, the effective density and resistivity based on the mean velocity are given. These can be used to obtain data on attenuation and absorption.

84-1749

Calculating Method and Experimental Investigation of Dynamic Characteristics of Tube in Tube Structure in Tall Buildings

Fan Xiaoqing and Zhang Weiyue

J. Bldg. Struc., 4 (3), pp 1-11 (1983)

CSTA No. 624-83.55

Key Words: Tubes, Concentric structures

A simplified calculation model is proposed for analyzing the dynamic characteristics of tube in tube structure. In this model, besides considering bending and shear deformation, the axial deformation of columns is taken into account.

84-1750

Simultaneous, Finite, Gyroscopic and Radial Oscillations of Hyperelastic Cylindrical Tubes

A. Ertepinar and T. Tokdemir

Middle East Technical Univ., Ankara, Turkey, Intl. J. Engrg. Sci., 22 (4), pp 375-382 (1984) 5 figs, 7 refs

Key Words: Tubes, Oscillation

Simultaneous, finite, gyroscopic and radial oscillations of long, circular cylindrical tubes are investigated. The material of the tube is assumed to be homogeneous, isotropic, hyperelastic and incompressible. The theory of finite elasticity is used in the formulation of the problem.

84-1751

Flow Induced Bifurcations to Three-Dimensional Oscillatory Motions in Continuous Tubes

A.K. Bajaj and P.R. Sethna

Purdue Univ., West Lafayette, IN 47907, SIAM J. Appl. Math., 44 (2), pp 270-286 (Apr 1984) 2 figs, 22 refs

Key Words: Tubes, Fluid-induced excitation

Three-dimensional motions of a cantilever tube carrying an incompressible fluid and having rotational symmetry about the vertical axis are examined for bifurcating oscillatory solutions. The system behavior depends on two parameters, ρ, the flow velocity and β, the mass ratio of the fluid and the tube.

84-1752

Subsonic Flapping Flutter

J.B. Grotberg and E.L. Reiss

The Technological Inst., Northwestern Univ., Evanston, IL 60201, J. Sound Vib., 92 (3), pp 349-361 (Feb 8, 1984) 7 figs, 12 refs

Key Words: Tubes, Fluid-induced excitation, Flutter

A mathematical model of two-dimensional flow through a flexible channel is analyzed for its stability characteristics. Linear theory shows that fluid viscosity, modeled by a Darcy friction factor, induces flutter instability when the dimensionless fluid speed, S, attains a critical flutter speed, S_0. This is in qualitative agreement with experimental results, and it is at variance with previous analytical studies where fluid viscosity was neglected and divergence instability was predicted.

84-1753

Stresses Caused by Waterhammer Loads in a Feedwater Piping System -- Results of Tests and Practical Applications (Beanspruchung einer Speisewasserleitung durch Druckstossbelastung -- Versuchsergebnisse und praktische Anwendungen)

L.M. Habip

Kraftwerk Union AG, Offenbach, W. Germany, Siemens Res. Dev. Repts., 12 (6), pp 386-394 (1983) 17 figs, 3 tables, 7 refs
(In German)

Key Words: Piping systems, Water hammer, Nuclear reactors

In the course of blowdown tests with a check valve the structural response of a feedwater piping system subjected to waterhammer loads is investigated. A simple theoretical formula is presented by means of which maximum dynamic strains in the plastic range, at locations where conventional stress limits are considerably exceeded, can be calculated on the basis of an elastic analysis only. Experimental results confirm this approach.

84-1754

Thermal Stratification in Steam Generator Feedwater Lines

R. Braschel, M. Miksch, and G. Schucktanz

IfB mbH, Stuttgart, W. Germany, J. Pressure Vessel Tech., Trans. ASME, 106 (1), pp 78-85 (Feb 1984) 14 figs, 8 refs

Key Words: Pipelines, Boilers, Fatigue life, Temperature effects

In recent years cracks have been found in the inlet nozzles of feedwater lines of steam generators. These cracks occur as a result of material fatigue. Thermal stratification in the feedwater is probably one of the factors primarily responsible for the fatigue. This paper describes methods of calculating the stress intensity ranges occurring as a result of the stratification. In addition, a design modification (a diversion tank) is proposed which effectively prevents the occurrence of this load case.

84-1755

Parametric Instability of a Periodically Supported Pipe Without and With Vibration Absorbers

A.K. Mallik, S.B. Kulkarni, and K.S. Ram

Indian Inst. of Tech., Kanpur, India 208016, J. Appl. Mech., Trans. ASME, 51 (1), pp 159-163 (Mar 1984) 4 figs, 8 refs

Key Words: Pipes (tubes), Vibration absorption (equipment), Dynamic absorbers

Parametric instability of a periodically supported pipe without and with dynamic absorbers is investigated. A method based on the notion of propagation constant is used. This method requires no prior knowledge of the mode shapes and renders the amount of computation independent of the number of spans. Numerical results are presented for single and two-span pipes. Effective control of the instability regions by means of dynamic absorbers is also demonstrated.

84-1756

Experimental Investigation of Piping Systems and Their Fixtures to Concrete Structures under Earthquake and Aircraft Impact Load Conditions (Experimentelle Untersuchung von Rohrleitungen und ihren Halterungen an Betonstrukturen unter Erdbeben- und Flugzeugabsturzbelastungen)

E. Haas and F. Steinwender

Kraftwerk Union AG, Offenbach, W. Germany, Siemens Res. Dev. Repts., 12 (6), pp 395-401 (1983) 8 figs, 4 tables
(In German)

Key Words: Piping systems, Supports, Seismic excitation, Crash research (aircraft)

Realistic tests of detailed modeled piping elements and system sections yielded by reason of nonlinear system behavior, a high degree of conservatism compared with linear elastic analysis. The peaks of stress and strain calculated with usual analytical methods were withstood without loss of structural integrity, in spite of exceeding the elastic range of material behavior by far. The precalculated anchor loads were considerably higher than the loads measured. These, in turn, were higher than the admissible anchor loads, but no failure of the pipe support occurred.

84-1757

A Comparative Study of Combination Methods Used in Response Spectrum Analysis of Nuclear Piping Systems

S. Gupta, D.P. Jhaveri, O. Kustu, and J.A. Blume
URS/John A. Blume & Associates, Engineers, San Francisco, CA 94105, J. Pressure Vessel Tech., Trans. ASME, 106 (1), pp 25-31 (Feb 1984) 3 figs, 7 tables, 9 refs

Key Words: Piping systems, Nuclear reactors, Seismic response

The different methods of combining responses for individual modes and directions for response spectrum analysis of nuclear piping systems are evaluated. For the purpose of the study, dynamic responses of 20 typical piping systems using nine different combination methods are systematically compared.

84-1758

Dynamic Tests of Cracked Pipe Components

D.A. Hale, J.D. Heald, and S.R. Sharma
General Electric Co., Nuclear Energy Business Operations, San Jose, CA 95125, J. Pressure Vessel Tech., Trans. ASME, 106 (1), pp 37-46 (Feb 1984) 22 figs, 2 refs

Key Words: Pipes (tubes), Cracked media, Steel, Dynamic tests

Dynamic tests were conducted involving notched sections of 4-in. (10-cm) stainless steel and Inconel-600 pipe. The specimen was a four-point bending beam with end masses sized to give an elastic first-mode frequency near that of typical field-installed piping systems (15 Hz). Specimens were loaded using sinewave excitation at this first mode natural frequency. Specimen response was compared to predictions from an elastic-plastic dynamic analysis previously developed on this program. Specimen loads at failure were also compared to those predicted from a net section collapse failure criterion.

84-1759

Modal Analysis Included in the Structural Dynamical Analysis of Large-bore Piping Systems (Modalanalyse im Rahmen des dynamischen Nachweises für grosse Rohrleitungen)

H.-J. Wehling, W. Schuz, W. Schrader, and F. Zerrmayr
Kraftwerk Union AG, Erlangen, W. Germany, Siemens Res. Dev. Repts., 12 (6), pp 379-385 (1983) 14 figs, 4 tables, 1 ref
(In German)

Key Words: Piping systems, Modal analysis, Finite element technique, Computer programs, Nuclear power plants

Finite-element-computer programs are used to precalculate the dynamic behavior of large-bore piping systems. Computer input is checked by random comparison of the results of computational and experimental modal analysis. Recently forced vibration tests were carried out at several nuclear power stations. Maximum tube dimensions were up to 680 mm O.D., 80 m in length, 100 t in weight. Computed and empirical eigenvalues agreed well.

DUCTS

84-1760

Dynamic Characteristics of a Jet Engine Test Facility Air Supply

M.L. Ross
Air Force Inst. of Tech., Wright-Patterson AFB, OH, Rept. No. AFIT/GAE/AA/83D-20, 154 pp (Dec 1983)
AD-A136 910

Key Words: Ducts, Jet engines, Test facilities

Dynamic response of a scale model of a test facility air supply ducting was determined experimentally over a frequency range from 20-200 Hz. Blocked lines with no flow and orifice terminated lines with a mean flow were used. The experiments examined the effects of signal input on three different lines and of using different size venturis. Gain and phase were measured upstream of the venturi and at the end of the line. Experimental results were compared with the results of a computer program based on Nichols' theory as modified by Krishnaiyer and Lechner.

BUILDING COMPONENTS

(Also see No. 1582)

84-1761

Some Remarks on Professor L. Cremer's Theory of the Coincidence Effect

H. Schaudinischky

Technion, Israel Inst. of Tech., Bldg. Res. Station, Technion City, Haifa 32000, Israel, Appl. Acoust., 17 (2), pp 111-124 (1984) 8 figs, 2 refs

Key Words: Walls, Sound transmission

The classical Coincidence Theory is based on a number of suppositions; in particular, on the unlimited extension of a wall. Under normal practical conditions this assumption must remain unrealized. In this elementary paper an attempt is made to describe the events during the passage of sound through a thin partition wall by dealing only with the sound field before and behind the wall. A numerical example is calculated.

84-1762

Inelastic Modeling and Seismic Analysis of Reinforced Masonry Shear Walls: Design Recommendations and Energy Methods

P. Soroushian

Ph.D. Thesis, Cornell Univ., 241 pp (1983)
DA8328631

Key Words: Walls, Reinforced concrete, Seismic analysis

The effects of inelasticity on the seismic response of structures are studied and design recommendations are developed for reinforced masonry shear walls. Based on a wide selection of experimental results, a new model is developed for the hysteretic behavior of reinforced masonry shear walls. This model considers the low energy absorption capacity and high deterioration of the walls. Inelastic response of typical single-story walls to a sufficiently large number of earthquakes with different intensities and frequency contents are obtained and presented by the spectrum curves of minimum required strength per unit weight. Seismic design recommendations for load-bearing masonry buildings are then developed on the basis of the equivalent lateral force and modal analysis procedures. An approximate energy-based method of inelastic seismic analysis is also proposed and applied to masonry walls. In this method seismic energy input to the system is calculated and related to the maximum displacement.

84-1763

R/C Member Cyclic Response During Various Loadings

Tze-How Hwang and C.F. Scribner

Sargent and Lundy Engrs., Chicago, IL, ASCE J. Struc. Engrg., 110 (3), pp 477-489 (Mar 1984) 13 figs, 3 tables, 19 refs

Key Words: Structural members, Reinforced concrete, Cyclic loading, Seismic response, Beams, Cantilever beams

An experimental investigation to determine the effect of variations in displacement history sequence and magnitude on cyclic response of reinforced flexural members is presented. Testing variables included shear stress as well as displacement history. Test results indicated that both member behavior and member energy dissipation capacity were functions of applied shear stress intensity and the magnitude of maximum displacements applied to the members.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

(Also see Nos. 1816, 1818)

84-1764

Applications of Active Attenuators in Controlling Low-Frequency Noise

W.K.W. Hong and Kh. Eghtesadi

Chelsea College, Univ. of London, Pulton Place, London SW6, UK, J. Low Frequency Noise Vib., 2 (1), pp 29-36 (1983) 15 figs, 21 refs

Key Words: Active attenuation, Active noise control, Noise reduction, Low frequencies

Increasing power consumption in recent years has led to the use of larger and more powerful machines which are, in most cases, sources of noise. Correspondingly, there have been increases in low-frequency sources. The current methods employed in controlling low-frequency noise are mainly passive, employing bulky insulating, as well as absorptive, materials to stop the noise transmitting from source to listener. The hardware is expensive and relatively inefficient in reducing low-frequency noise. This is an area where active attenuators are particularly useful due to their ability to operate at low frequencies. Considerable work has been carried out to apply active attenuators to the controls of transformer noise, engine exhaust noise, and duct-borne noise.

84-1765

Noise of Rotating Yarn in Textile Machines

F. Angrilli and V. Cossalter
Istituto di Meccanica Applicata alle Macchine, Facolta di Ingegneria, Universita di Padova, Via Venezia, 1-35100 Padova, Italy, Noise Control Engrg. J., 22 (2), pp 48-53 (Mar/Apr 1984) 7 figs, 11 refs

Key Words: Yarns, Textile looms, Industrial facilities, Noise generation

An experimental and theoretical study of sound radiation from a rotating yarn in textile machines is presented. The mathematical model is developed from the basic acoustical equations of the sound field radiated by a time varying point force in arbitrary motion, derived in a convenient form by Lowson. Experimental results obtained with a single rotating yarn show reasonable agreement for trends and good agreement for peak levels and frequencies. The importance on the pressure level of the direction of the observer with respect to the ballon axis direction is stressed.

84-1766

Industrial Noise Control: Architectural and Environmental Aspects. 1975 - January, 1984 (Citations from the International Information Service for the Physics and Engineering Communities Data Base)

NTIS, Springfield, VA, 174 pp (Jan 1984)
PB84-857408

Key Words: Industrial facilities, Noise reduction, Bibliographies

This bibliography contains 235 citations concerning architectural and engineering acoustics associated with noise control in industrial environments. Important sources of industrial noise and the level of exposure of workers to noise are examined. Methods of active attenuation of noise; i.e., the cancelling of noise from a source by the addition of further noise, including both absorptive and non-absorptive methods are presented.

84-1767

On the Acoustic Pressure at the Surface of Circular Radiators (Über den Schalldruck an der Oberfläche von kreisförmigen Strahlern)

H. Fleischer
Institut f. Mechanik, Fachbereich Luft- und Raumfahrt, Hochschule der Bendeswehr Munchen, Acustica, 54 (3), pp 161-171 (Jan 1984) 10 figs, 19 refs
(In German)

Key Words: Acoustic excitation

The acoustic pressure on the surface of planar circular structures, fitted in an infinitely large baffle, is calculated according to the Huygens-Rayleigh principle. A few simple non-axisymmetric vibrational-mode shapes are considered. The necessary integration is done numerically with the aid of a desk computer.

84-1768

Time Spread of Acoustic Signals Reflecting from a Fixed Rough Boundary

M.H. Brill, X. Zabal, and S.L. Adams
Science Applications, Inc., 1710 Goodridge Dr., McLean, VA 22102, J. Acoust. Soc. Amer., 75 (4), pp 1062-1070 (Apr 1984) 10 figs, 13 refs

Key Words: Sound waves, Wave propagation, Wave reflection

The time spreading of a spherical-wave impulse of acoustic power reflecting from a not-too-rough fixed boundary (such as an ocean bottom) is computed using a simple geometric-acoustic model. In the model a ray reflects specularly from each boundary facet, and arrives at the receiver if, and only if, the position and slope of the facet provide the requisite specular path. In this way, the probability of reception of a ray from a particular facet is tied to the slope distribution of the reflecting boundary (assuming the depth is constant). A general expression for time spread is derived, and computed time spreads are presented for particular source/receiver geometries.

84-1769

A Finite Difference Solution for the Propagation of Sound in Near Sonic Flows

S.I. Hariharan and H.C. Lester
Inst. for Computer Applications in Science and Engrg., Mail Stop 132C, NASA Langley Res. Ctr., Hampton, VA 23665, J. Acoust. Soc. Amer., 75 (4), pp 1052-1061 (Apr 1984) 11 figs, 1 table, 12 refs

Key Words: Sound waves, Wave propagation

An explicit time/space finite difference procedure is used to model the propagation of sound in a quasi-one-dimensional duct containing high Mach number subsonic flow. Nonlinear acoustic equations are derived by perturbing the time-dependent Euler equations about a steady, compressible mean flow. The governing difference relations are based on a fourth-order, two-step (predictor-corrector) MacCormack scheme. Difference equations for the source and termination boundary conditions are derived from the appropriate characteristic relationships. The solution algorithm functions by switching on a time harmonic source and allowing the difference equations to iterate to a steady state. A significant advantage with this approach is that the nonlinear terms can be retained and evaluated with only modest additional computer cost above that required for a linear model calculation.

84-1770

Distortion and Harmonic Generation in the Nearfield of a Finite Amplitude Sound Beam

S.I. Aanonsen, T. Barkve, J.N. Tjotta, and S. Tjotta
The Univ. of Bergen, 5000 Bergen, Norway, J. Acoust. Soc. Amer., 75 (3), pp 749-768 (Mar 1984) 11 figs, 2 tables, 39 refs

Key Words: Sound waves, Wave propagation

Distortion and harmonic generation in the nearfield of a finite amplitude sound beam are considered, assuming time-periodic but otherwise arbitrary on-source conditions. The basic equations of motion for a lossy fluid are simplified by utilizing the parabolic approximation, and the solution is derived by seeking a Fourier series expansion for the sound pressure. The harmonics are governed by an infinite set of coupled differential equations in the amplitudes, which are truncated and solved numerically. Amplitude and phase of the fundamental and the first few harmonics are calculated along the beam axis, and across the beam at various ranges from the source. Two cases for the source are considered and compared.

84-1771

Sound Field in a Rectangular Enclosure with Diffusely Reflecting Boundaries

R.N. Miles
The Boeing Co., P.O. Box 3707, Seattle, WA 98124, J. Sound Vib., 92 (2), pp 203-226 (Jan 22, 1984) 10 figs, 1 table, 6 refs

Key Words: Enclosures, Rooms, Sound waves, Wave reflection, Walls

The sound field is determined in a three dimensional rectangular enclosure with nonuniformly absorbent and diffusely reflecting walls. The method consists of solving the geometrical acoustics integral equation for enclosures containing either steady state or time-varying sources. These solutions are an improvement over classical geometrical acoustics in which it is assumed that the reverberant field is diffuse in both the steady state and during decay. The conditions in which the classical methods can lead to errors are shown and simple approximate formulas are presented which comprise a correction to Sabine's decay time formula for the average absorption coefficient of reverberation chambers with absorbent test samples.

84-1772

The Combined Effects of Fluid Loading and Compliant Coating on the Acoustic and Structural Fields of an Infinite Plane Elastic Surface

D.G. Crighton
Univ. of Leeds, Leeds LS2 9JT, UK, J. Sound Vib., 92 (2), pp 237-252 (Jan 22, 1984) 14 refs

Key Words: Membranes (structural members), Coatings, Fluid-induced excitation, Elastic systems, Sound waves, Wave propagation

This paper deals with the combined effects of fluid loading and compliant coating on an elastic surface, taken to be a membrane, under uniform line force excitation. The parameters defining a coating may be chosen either to decouple the fluid from the surface vibration and thereby reduce the far field radiation, or to cancel fluid loading effects and restore the far field to the level and directivity corresponding to the vibration of a surface without fluid loading. In both cases there may be attendant changes in the structural vibration levels, either close to the excitation or far from it. These changes are examined in a comprehensive fashion, the drive and transfer admittances and the acoustic far field being calculated for excitation at prescribed force amplitude, at prescribed velocity amplitude, and for prescribed input power.

84-1773

Review of Sound Induced by Vortex Shedding from Cylinders

R.D. Blevins

GA Technologies, Inc., San Diego, CA 92138, J. Sound Vib., 92 (4), pp 455-470 (Feb 22, 1984) 8 figs, 91 refs

Key Words: Cylinders, Vortex shedding, Sound generation

Sound induced by periodic vortex shedding from cylinders has been studied more or less continuously since the first quantitative study by Strouhal in 1878. Measurements have shown that vortex shedding is a dipole source of sound. Theoretical models for aeroacoustic sound in a free space, mostly inspired by Lighthill's work, have been developed which can replicate the measurements once the vortex shedding force, coherence, and periodicity are experimentally measured. Vortex shedding from tubes in heat exchanger tube bundles can reach damaging intensities because the acoustic mode is bound by the lower speed of sound within the tube bank itself. However, the amplitude and occurrence of the resonance can only be approximately predicted at present.

84-1774

Noise Assessment Guidelines

Bolt Beranek and Newman, Inc., Cambridge, MA, Rept. No. HUD-0002932, HUD/PDR-735, 36 pp (June 1983)

PB84-151133

Key Words: Traffic noise, Airports

This manual describes those procedures that have been developed so those without technical training will be able to assess the exposure of a housing site to present and future noise conditions. It provides a means for assessing separately the noise produced by airport, highway, and railroad operations, as well as the means for aggregating their combined effort on the overall noise environment at a site. The text explains how to combine sound levels in decibels and how the noise level on larger sites may vary at different parts of the site. The only materials required to make the noise assessment are a map of the area, a straight edge ruler, a protractor, and a pencil.

84-1775

SEACAL Digital Data Processing Buoy Acoustic Performance During BERMEX-83: Quick Look Report

P.D. Herstein and P.C. King

Naval Underwater Systems Ctr., New London, CT, Rept. No. NUSC-TM-831145, 31 pp (Sept 14, 1983)

AD-A135 494

Key Words: Underwater sound, Hydrophones, Buoys, Fast Fourier transform, Data processing

A new multi-hydrophone digital buoy system with onboard FFT processing has been developed. Acoustic data from each of eight hydrophones is digitized and real time fast Fourier transformed by the buoy's micro-processor. Complex and ensemble averaged spectral results are then written onto a high density digital cartridge tape. An instantaneous dynamic range of at least 72 dB is available over the frequency band 4-350 Hz. The first open ocean test of the system performed nearly flawlessly and was recovered intact. Over 75 hours of acoustic data were acquired, including both ambient noise and CW tow measurements. This technical memorandum presents a quick look review of the acoustic results of the sea test.

84-1776

Using Eigenvalue Analysis to Identify Interference in Ambient Sea Noise Vertical Directionality Measurements

D.J. Kewley

Dept. of Defence, Weapons Systems Res. Lab., Defence Res. Centre, Salisbury, South Australia 5108, J. Acoust. Soc. Amer., 75 (3), pp 826-833 (Mar 1984) 15 figs, 22 refs

Key Words: Underwater sound, Sound measurement, Eigenvalue problems

Ambient noise vertical directionality measurements at low frequencies have shown that noise arrives from long distances at near horizontal angles, from moderate distances at larger angles, and from local sources at high angles. Levels of noise from different sources can be measured by examining vertical linear array beam powers a the appropriate angles. However, when measurements are made, it is important to be able to distinguish between acoustic signals, ambient noise, and data contamination. Some experimental results are examined, using conventional and adaptive beamforming and eigenvalue – eigenvector decomposition, and used to establish criteria useful in deciding whethter the measurements are ambient noise or otherwise.

84-1777

Radiation and Diffraction of Underwater Acoustic Waves

Y.H. Pao, C.P. Chen, and G.C.C. Ku

Dept. of Theoretical and Applied Mechanics, Cornell Univ., Ithaca, NY, Rept. No. SBI-AD-E001 629, 137 pp (July 31, 1983)
AD-A136 827

Key Words: Underwater sound, Sound waves, Wave radiation, Wave diffraction, Circular shells, Cylindrical shells, Shells

Research results are shown in three technical reports included in this report. The titles are: Acoustic Radiations of a Submerged Cylindrical Shell, Acoustic Radiation from a Submerged Finite Circular Cylindrical Shell Driven by a Harmonic Force and Attenuation Constants and Phase Velocities of Eighteen Polymeric Materials.

SHOCK EXCITATION

(Also see Nos. 1762, 1817, 1835, 1849, 1855)

84-1778

Reinforced Concrete Response to Near Field Explosions

T.M. Baseheart
Dept. of Civil and Environmental Engrg., Univ. of Cincinnati, OH, Rept. No. AFOSR-TR-83-1064, 49 pp (June 20, 1983)
AD-A135 876

Key Words: Reinforced concrete, Blast response

From a review of experimental test results for concrete slabs subjected to conventional blast loading, various failure mechanisms and their relationship to scaled breach distance are documented. Analytical studies demonstrate the failure of membrane action when included with the rigid flexural analysis of structural response. For more intense blast pressure intensities, procedures available in the literature are described.

VIBRATION EXCITATION

(Also see No. 1790)

84-1779

Complex Eigenvalues for the Stability of Couette Flow

R.C. Diprima and P. Hall
NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-CR-172251, 49 pp (Oct 1983)
N84-13492

Key Words: Concentric structures, Cylinders, Fluid-induced excitation, Eigenvalue problems

The eigenvalue problem for the linear stability of Couette flow between rotating concentric cylinders to axisymmetric disturbances is considered. It is shown by numerical calculations and by formal perturbation methods that when the outer cylinder is at rest there exist complex eigenvalues corresponding to oscillatory damped disturbances. The structure of the first few eigenvalues in the spectrum is discussed.

84-1780

Nonlinear Sloshing Analysis of Liquid in Containers with Arbitrary Geometries

K. Komatsu
Natl. Aerospace Lab., Tokyo, Japan, Rept. No. NAL/TR-757, 23 pp (1983)
PB84-137363
(In Japanese)

Key Words: Fluid-filled containers, Sloshing

A method is presented for calculating the nonlinear dynamic behavior of liquid in containers with arbitrary geometries. The present formulation is based on the numerical perturbation technique, which uses the orthogonality of the mode shapes and yields nonlinear coupled ordinary differential equations describing the temporal behavior. The linear mode shapes are obtained by numerical or analytical methods, and the equations describing the temporal behavior are solved by the classical perturbation method.

84-1781

Laser Holographic Interferometry for an Unsteady Airfoil Undergoing Dynamic Stall

G. Lee, D.A. Buell, J.P. Licursi, and J.E. Craig
NASA Ames Res. Ctr., Moffett Field, CA, AIAA J., 22 (4), pp 504-511 (Apr 1984) 10 figs, 10 refs

Key Words: Airfoils, Stalling, Fluid-induced excitation

Laser holographic interferometry was used to study a two-dimensional airfoil undergoing dynamic stall. The airfoil, fabricated from graphite fiber and epoxy, was tested at Mach numbers of 0.3 - 0.6, Reynolds numbers of 0.5×10^6 to 2.0×10^6, reduced frequencies of 0.015 - 0.15, and mean angles of attack of 0 - 10 deg with amplitudes of 10 deg. Density and pressure fields were obtained from dual-plate interferograms. Double-pulse interferograms were also taken.

84-1782

On the Effect of Axial Compression on the Bounds of Simple Harmonic Motion

V. Birman, I. Elishakoff, and J. Singer
Dept. of Aeronautical Engrg., Technion -- Israel Inst. of Tech., Haifa, Israel, Israel J. Tech., 20 (6), pp *254-267 (1982) 13 figs, 16 refs*

Key Words: Axial force, Harmonic response

Nonlinear forced motion of one-degree-of-freedom statically compressed systems with cubic nonlinearity is studied. An approximate analytical criterion is employed to establish the bounds of driving force frequencies corresponding to the domination of simple harmonic motion. These analytical bounds are compared with those obtained by numerical integration.

84-1783

Continued Experimental Investigation of Dynamic Stall

S.J. Schreck
Air Force Inst. of Tech., Wright-Patterson AFB, OH, Rept. No. AFIT/GAE/AA/83D-21, 147 pp (Dec 1983)
AD-A136 920

Key Words: Airfoils, Fluid-induced excitation, Stalling

Flow over an airfoil undergoing a constant rate of change of angle of attack was experimentally studied over a range of tunnel speeds and rotation rates. Surface pressure transducers coupled with a microcomputer-based data acquisition system were used to collect surface-pressure data at the rate of 4000 samples per second; data reduction was also microcomputer-based.

84-1784

Investigation of Effects Contributing to Dynamic Stall Using a Momentum-Integral Method

J.S. Lawrence
School of Engrg., Air Force Inst. of Tech., Wright-Patterson AFB, OH, Rept. No. AFIT/GAE/AA/83D-12, 108 pp (Dec 1983)
AD-A136 897

Key Words: Airfoils, Fluid-induced excitation, Wind-induced excitation, Stalling

Dynamic stall effects are analyzed in this investigation for cases of an inertially static airfoil in a flow field rotating at constant rate (gust response), and an airfoil pitching at constant rate in a steady flow field. The method used is a boundary layer solution of the momentum-integral equation by a modified von Karman-Pohlhausen technique. Previous work using this method to match Kramer's experimental results for gust response is reviewed, corrected, and continued. The validity of the closure equation and the assumptions key to its derivation are examined.

84-1785

Airfoil Shape and Thickness Effects on Transonic Airloads and Flutter

S.R. Bland and J.W. Edwards
NASA Langley Res. Ctr., Hampton, VA, J. Aircraft, 21 (3), pp 209-217 (Mar 1984) 14 figs, 12 refs

Key Words: Airfoils, Geometric effects, Flutter

A transient pulse technique is used to obtain harmonic forces from a time-marching solution of the complete unsteady transonic small-perturbation potential equation. The unsteady pressures and forces acting on a model of the NACA 64A010 conventional airfoil and the MBB A-3 supercritical airfoil over a range of Mach numbers are examined in detail.

84-1786

On the Dynamic Behavior of the Wobblestone

R.E. Lindberg, Jr. and R.W. Longman
Aerospace Syst. Div., Naval Res. Lab., Washington, DC 20375, Acta Mech., 49 (1/2), pp 81-94 (1983) 10 figs, 5 refs

Key Words: Rotating structures, Vibration response

The wobblestone is a generalized form of a top with distinct inertias and a nonspherical surface at the point of contact to the horizontal plane on which it moves. Some wobblestones exhibit a curious property of allowing steady rotation about the vertical principal inertia axis only when rotated in one direction, while other wobblestones exhibit repeated reversals of the direction of rotation after being spun. Nonlinear equations governing the motion of a wobblestone are derived assuming no slippage at the point of contact to the supporting rigid plane, which corresponds to a conservative model. The equations are formulated in a manner suitable for numerical integration. The major observed properties of the motion of these asymmetrical tops are demonstrated in numerical simulations.

84-1787

Parametric Excitation in the Self-Excited Vibration System with Dry Friction (1st Report, Parametric Resonance)

S. Yano

Fukui Univ., 3-9-1, Bunkyo, Fukui, Japan, Bull. JSME, 27 (224), pp 255-262 (Feb 1984) 15 figs, 3 refs

Key Words: Parametric excitation, Coulomb friction, Parametric resonance

An application of solutions of linear Mathieu equation by a new method gives approximate solutions in a parametrically excited self-excitation system with dry friction. Steady solutions and stability in the regions of parametric resonance of first and second orders are determined. Solutions outside the regions of parametric resonances are approximated by two limit cycles.

84-1788

Parametric Excitation in the Self-Excited Vibration System with Dry Friction (2nd Report, In the Neighborhood of the Region of Parametric Resonance)

S. Yano

Fukui Univ., 3-9-1, Bunkyo, Fukui, Japan, Bull. JSME, 27 (224), pp 263-270 (Feb 1984) 13 figs, 2 refs

Key Words: Parametric excitation, Coulomb friction, Parametric resonance, Critical speeds

In parametrically excited self-excitation systems with dry friction, approximate solutions outside the regions of parametric resonance of second order are obtained. Approximate solutions in the neighborhood of parametric resonance of first order are obtained and critical frequencies where beat vibrations occur and disappear can be determined by the points of intersection of these solutions and parametric resonance curves of first order. By numerical results it is ascertained that this determination method of critical frequencies has high accuracy and the interaction between parametric excitation and self-excited vibration is discussed.

THERMAL EXCITATION

(See Nos. 1768, 1769)

MECHANICAL PROPERTIES

DAMPING

(Also see Nos. 1578, 1632, 1640)

84-1789

Usefulness of Impact Dampers for Space Applications

B.W. Gibson

School of Engrg., Air Force Inst. of Tech., Wright-Patterson AFB, OH, Rept. No. AFIT/GA/AA/83M-2, 147 pp (Mar 1983)

AD-A135 695

Key Words: Shock absorbers, Experimental data, Computerized simulation

The usefulness of the impact damper in eliminating vibrations is studied analytically and experimentally. Laboratory models of vibrating systems are constructed to evaluate the performance of the impact damper in reducing or eliminating forced and free vibrations. A computer simulation of a single degree-of-freedom primary system in free vibration employing an impact damper is constructed for the same purpose. Laboratory free vibration results are compared to the computer simulation in order to judge its accuracy.

84-1790

Initial Estimates of Damping Rates and Frequencies

T.G. Ryall

Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL-STRUC-NOTE-485, AR-002-943, 13 pp (Mar 1983)

N84-13879

Key Words: Damping coefficients, Natural frequencies, Fourier transformation

A simple, quick method for obtaining frequencies and damping ratios from Fourier transforms was devised. Single pole-single zero approximation, equation of Nyquist locus, and two zeros-two poles approximation are addressed.

84-1791

Fundamental Investigation on an Oil Damper (3rd Report, Comparison of Analyses Based on Cylindrical Coordinates and Cartesian Coordinates)

T. Asami and H. Sekiguchi
Himeji Inst. of Tech., 2167, Shosha, Himeji, Hyogo, 671-22, Japan, Bull. JSME, 27 (224), pp 309-316 (Feb 1984) 5 figs, 3 tables, 5 refs

Key Words: Dampers, Oil dampers, Damping coefficients

This paper deals with a theoretical research of an oil damper whose piston is vibrating in a viscous fluid filling a fixed circular cylinder. In the previous report, transforming the annular clearance between the cylinder and the piston into a straight channel, the authors induced a drag force acting on the piston from an equation of motion of the fluid expressed in Cartesian coordinates. Therefore the result of this analysis contained an error due to the transformation. In this report, the authors try to derive a more exact value using an equation represented in cylindrical coordinates.

84-1792

Measurement of Rolling Friction by a Damped Oscillator

M. Dayan and D.H. Buckley
NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. E-1583, NASA-TP-2257, 8 pp (Dec 1983)
N84-13577

Key Words: Rolling friction, Measurement techniques

An experimental method for measuring rolling friction is proposed. The method is mechanically simple. It is based on an oscillator in a uniform magnetic field and does not involve any mechanical forces except for the measured friction. The measured pickup voltage is Fourier analyzed and yields the friction spectral response. The proposed experiment is not tailored for a particular case. Instead, various modes of operation, suitable to different experimental conditions are discussed.

FATIGUE

(Also see No. 1603)

84-1793

Concrete in Biaxial Cyclic Compression

O. Buyukozturk and Tsi-Ming Tseng
Massachusetts Inst. of Tech., Cambridge, MA 02139, ASCE J. Struc. Engrg., 110 (3), pp 461-476 (Mar 1984) 14 figs, 1 table, 24 refs

Key Words: Concretes, Cyclic loading, Fatigue life

An experimental program was conducted to study the behavior of concrete under low-cycle high amplitude biaxial cyclic compression. Biaxial loading was achieved by subjecting square concrete plates to in-plane loading where compressive stress was applied in one direction while confining the deformation of the specimen in the orthogonal direction. Three main types of tests were performed: monotonic loading to failure; cycling of compressive stresses to a limiting envelope curve; and cycling of compressive stresses to prescribed values.

84-1794

On the Relationship Between Fatigue Limit, Threshold and Microstructure of a Low-Carbon Cr-Ni Steel

Li Nian, Du Bai-ping, and Zhou Hui-jiu
Res. Inst. for Strength of Materials, Xi'an Jiaotong Univ., Xi'an, Shaanxi Province, People's Rep. of China, Intl. J. Fatigue, 6 (2), pp 89-94 (Apr 1984) 13 figs, 7 tables, 5 refs

Key Words: Fatigue life, Steel

The relationship between the fatigue limit stress range, $\Delta\sigma_w$, the threshold stress intensity factor, ΔK_{th}, and microstructure of low-carbon 12CrNi3A steel has been investigated. Nonpropagating microcracks were observed on the surface of smooth specimens which had been subjected to at least 5×10^6 cycles at the fatigue limit stress. The size of the cracks depended on the characteristic sizes of the microstructure of the material. Scanning electron microscopy showed that the fractographic characteristics in the near-threshold region of fatigue macrocrack growth were similar to those in the fatigue microcrack initiation region. This implies that the fatigue limit and fatigue threshold of the material have a similar physical meaning, both signifying the resistance of the material to the propagation of fatigue cracks.

84-1795

A Cumulative Damage Theory for Fatigue Crack Initiation and Propagation

D. Kujawski and F. Ellyin

Inst. of Machine Design Fundamentals, Warsaw Technical Univ., Warsaw, Narbutta 84, Poland, Intl. J. Fatigue, 6 (2), pp 83-88 (Apr 1984) 4 figs, 22 refs

Key Words: Fatigue life, Crack propagation

A method for evaluating the cumulative damage resulting from the application of cyclic stress (or strain) sequences of varying amplitude is presented. Both the crack initiation and propagation stages of the fatigue failure process are included. The development is based on the concept of plastic strain energy dissipation as a function of cyclic life. The damage accumulated at any stage is evaluated from a knowledge of the fatigue limit in the initiation phase and an apparent limit obtained through fracture mechanics for the propagation phase. The proposed damage theory is compared with two-level strain cycle test data of thin-walled specimens, and is found to be in fairly good agreement.

84-1796

Effect of Environment on the Low Cycle Fatigue Behaviour of Cast Nickel-Base Superalloy IN738LC

Guo Jianting, D. Ranucci, E. Picco, and P.M. Strocchi

Inst. of Metal Res., Academia Sinica, Shenyang, People's Rep. of China, Intl. J. Fatigue, 6 (2), pp 95-99 (Apr 1984) 13 figs, 7 refs

Key Words: Fatigue tests, Alloys

Low cycle fatigue tests were conducted on cast nickel-base superalloy IN738LC in vacuum and air and on specimens coated with a layer of NaCl and Na_2SO_4 at 900°C and two different strain rates. The fatigue life, determined in terms of the cyclic plastic strain, decreased markedly as the severity of the environment increased. The marked strain-rate effect found in air and saline environments disappeared when the experiments were conducted in a vacuum.

84-1797

The Effect of Mean Stress on Delay in Fatigue Crack Growth under Load Stepdown

D.L. McDiarmid, W. Choy, and T.M. Lee

The City Univ., Northampton Square, London EC1V OHB, UK, Intl. J. Fatigue, 6 (2), pp 101-105 (Apr 1984) 6 figs, 3 tables, 31 refs

Key Words: Fatigue life, Crack propagation

The effect of mean stress together with decreasing stress range on fatigue crack propagation behavior in mild steel is investigated. The delay period between crack arrest and repropagation is found to be a function of the maximum stress intensity factor stepdown ratio, K_{2max}/K_{1max}. Delay only occurs when this ratio is less than unity.

84-1798

Mixed-Mode Fatigue Crack Growth under Biaxial Loading

R.K. Pandey and A.B. Patel

Dept. of Applied Mechanics, Indian Inst. of Tech., New Delhi-110016, India, Intl. J. Fatigue, 6 (2), pp 119-123 (Apr 1984) 7 figs, 13 refs

Key Words: Fatigue life, Crack propagation

Studies on crack growth in a panel with an inclined crack subjected to biaxial tensile fatigue loading are presented. The strain energy density factor approach is used to characterize the fatigue crack growth. The crack growth trajectory as a function of the initial crack angle and the biaxiality ratio is also predicted. The analysis is applied to 7075-T6 aluminium alloy to predict the dependence of crack growth rate on the crack angle.

84-1799

Impact and Subsequent Fatigue Damage Growth in Carbon Fibre Laminates

W.J. Cantwell, P.T. Curtis, and J. Morton

Dept. of Aeronautics, Imperial College of Science and Tech., Prince Consort Rd., South Kensington, London SW7 2BY, UK, Intl. J. Fatigue, 6 (2), pp 113-118 (Apr 1984) 9 figs, 15 refs

Key Words: Layered materials, Fatigue life

The influence of the ply stacking sequence on the impact resistance and subsequent 0-tension fatigue performance of carbon fiber laminates has been investigated. Drop-weight impact tests were conducted on a range of 16 ply carbon fiber laminates with either all non-woven plies or mixtures of woven and non-woven plies. Damaged coupons w... sted in 0-tension fatigue for up to 10^6 cycles, scanned using an ultrasonic probe and then loaded in tension until failure.

84-1800

Development of Fatigue and Crack Propagation Design and Analysis Methodology in a Corrosive Environment for Typical Mechanically-Fastened Joints. Volume 1. Phase 1 Documentation

Y.H. Kim, R.P. Wei, D.E. Gordon, S.M. Speaker, and S.D. Manning
General Dynamics, Fort Worth, TX, Rept. No. NADC-83126-60-VOL-1, 237 pp (Mar 1983)
AD-A136 414

Key Words: Joints (junctions), Fatigue life, Crack propagation, Corrosion fatigue

A corrosion fatigue methodology has been developed for predicting the crack initiation and crack propagation behavior of mechanically-fastened joints. An experimental test program was also conducted using 7075-T7651 aluminum alloy and beta-annealed Ti-6A1-4V alloy to evaluate the effects of environment, test frequency, R-ratio, holding-time, and stress level on corrosion fatigue behavior. Based on this investigation, it was concluded that the reaction between aqueous environments and the 7075-T7651 aluminum alloy appears to be limited.

84-1801
Development of Fatigue and Crack Propagation Design and Analysis Methodology in a Corrosive Environment for Typical Mechanically-Fastened Joints. Volume 2. State-of-the-Art Assessment
Y.H. Kim, S.M. Speaker, R.P. Wei, and S.D. Manning
General Dynamics, Fort Worth, TX, Rept. No. NADC-83126-60-VOL-2, 86 pp (Mar 1983)
AD-A136 415

Key Words: Joints (junctions), Fatigue life, Crack propagation, Corrosion fatigue

Navy corrosion fatigue design requirements for metallic airframes and general design practices for satisfying these requirements are briefly reviewed. The phenomenon of and mechanisms responsible for corrosion fatigue crack intiation are reviewed. The mechanisms discussed include the stress-concentration pit mechanism, the film rupture mechanism, and the preferential dissolution mechanism. Two fracture mechanics models are described and discussed for quantitatively predicting the number of cycles to corrosion fatigue crack initiation: stress-initiation life model and strain-initiation life model.

84-1802
Bending Fatigue of High-Yield Reinforcing Bars in Concrete
D.S. Moss
Transport and Road Research Lab., Crowthorne, UK, Rept. No. TRRL-SUPPLEMENTARY-748, 23 pp (1982)
PB84-142769

Key Words: Bars, Reinforced concrete, Fatigue life, Flexural vibration

Continuous and butt-welded specimens of three types of high-yield reinforcing bars in concrete were fatigue tested in bending. Frequency was 3 Hz and endurances were up to 100 x 1,000,000 cycles. The performance of the bars was higher than that of similar bars tested axially in air. A modified form of a previously accepted relationship between the stress range and the number of cycles to failure is described.

84-1803
The Influence of Environment and Stress Ratio on the Low Frequency Fatigue Crack Growth Behaviour of Two Medium-Strength Quenched and Tempered Steels
B.F. Jones
Naval Aircraft Materials Lab., RN Aircraft Yard, Fleetlands, Gosport, Hants PO13 OAW, UK, Intl. J. Fatigue, 6 (2), pp 75-81 (Apr 1984) 8 figs, 1 table, 22 refs

Key Words: Fatigue life, Crack propagation, Steel

The results of low frequency corrosion fatigue crack growth tests on HY130 and Q1N steels are reported and compared. The similarities and differences in the response of the two steels to variations in environment and stress ratio are highlighted and discussed in terms of some recent theories of corrosion fatigue crack growth and the impurity element embrittlement of grain boundaries.

84-1804
Simple Fatigue Life Calculations for Synchronous Excitation Based on the Mohr's Failure Limit (Einfache Schwingfestigkeitsrechnung für synchrone Beanspruchung auf der Basis der Versagensgrenze nach Mohr)
E. El-Magd

RWTH, Aachen, Fed. Rep. Germany, Konstruktion, 36 (2), pp 59-64 (Feb 1984) 7 figs, 20 refs
(In German)

Key Words: Fatigue life

Based on Mohr's failure limit, a calculation of fatigue life of materials with arbitrary tension-pressure to torsional fatigue ratio is presented.

84-1805

Resonance Controlled Fatigue Crack Propagation in Cylindrical Shafts under Combined Loading

A.J. Dentsoras and A.D. Dimarogonas
Univ. of Patras, Patras, ASME Paper No. WA/DE-26

Key Words: Fatigue life, Crack propagation, Structural members, Shafts

Fatigue crack growth in resonating structural members under combined loading is studied. It was found that material damping is the decisive factor determining the crack growth rate. This influence appears to be more profound for tensile than for torsional loading.

84-1806

Path-Independent Integral and Moving Isoparametric Elements for Dynamic Crack Propagation

T. Nishioka and S.N. Atluri
Georgia Inst. of Tech., Atlanta, GA, AIAA J., 22 (3), pp 409-414 (Mar 1984) 7 figs, 2 tables, 19 refs

Key Words: Crack propagation

The objective of this paper is to present a procedure based on moving (or shifting) isoparametric elements for the analysis of dynamic crack propagation. The fracture parameters, such as the stress intensity factors or energy release rates for dynamically propagating cracks, are evaluated by far-field path-independent integrals. The combined use of the moving isoparametric elements and the path-independent integrals gives excellent results as compared to those obtained by other techniques.

84-1807

Transient Stress Intensity Factors of an Interfacial Crack Between Two Dissimilar Anisotropic Half-Spaces. Part 1: Orthotropic Materials

A.-Y. Kuo
NUTECH Engineers, Inc., San Jose, CA 95119, J. Appl. Mech., Trans. ASME, 51 (1), pp 71-76 (Mar 1984) 4 figs, 19 refs

Key Words: Cracked media, Stress intensity factors, Orthotropism

Transient response of an interfacial crack between two dissimilar elastic, orthotropic solids is investigated. The interfacial crack is excited by tractions suddenly applied on the crack surfaces. Governing equations, boundary conditions, and continuity conditions along the interface are reduced to a singular integral equation. Solution of the singular integral equation is obtained by the use of Jacobi polynomials. Expressions for stress intensity factors at the crack tip are given.

84-1808

Resonance Effects for a Crack Near a Free Surface

L.M. Keer, W. Lin, and J.D. Achenbach
Northwestern Univ., Evanston, IL 60201, J. Appl. Mech., Trans. ASME, 51 (1), pp 65-70 (Mar 1984) 6 figs, 1 table, 16 refs

Key Words: Cracked media, Harmonic excitation, Resonance

Stress intensity factors are computed for a horizontal subsurface crack that is subjected to time harmonic excitation. The problem is analyzed by determining displacement potentials that satisfy reduced wave equations and specified boundary conditions. The formulation of the problem leads to a system of coupled integral equations for the dislocation densities. The numerical solution of the integral equations leads directly to the stress intensity factors.

84-1809

An Elastodynamic Analysis of the Single Edge Notch Specimen

M. Perl
Technion -- Israel Inst. of Tech., Haifa 32000, Israel, Israel J. Tech., 20 (6), pp 259-267 (1982) 6 figs, 2 tables, 8 refs

Key Words: Elastodynamic response, Crack propagation

A two-dimensional linear elastodynamic analysis of fast crack growth in the single edge notch specimen is presented. The influence of the initial crack length and the initial loading (bluntness) are pursued. The analysis is performed using the finite-difference SMF2D code in its generation mode. Once the crack tip motion is specified, using experimental data, the dynamic stress intensity factor, the dynamic energy release rate, and the energy distributions are evaluated throughout the various simulations.

84-1810

Fracture Behavior under Impact

J.F. Kalthoff and S. Winkler

Fraunhofer-Gesellschaft zuer Foerderung der Angewandten Forschung e.V., Freiburg im Bressau, Fed. Rep. Germany, Rept. No. W-8/83, 45 pp (Jan 1982), AD-A136 054; Rept. No. W-9/83, 21 pp (July 1982), AD-A136 055; Rept. No. W10/83, 49 pp (Jan 1983), AD-A136 056; Rept. No. W-11/83, 83 pp (July 1983), AD-A136 057

Key Words: Impact excitation, Crack propagation

The physical behavior of cracks under impact loading is investigated. Single edge cracks or arrays of multiple cracks in rectangular specimens are considered. The specimens are loaded by time dependent tensile stress pulses moving perpendicular to the crack direction. The specimens are directly loaded by an impinging projectile or by a base plate which is accelerated by a projectile. The specimens are made from a transparent model material or a high strength steel. The initial crack lengths and impact velocities are varied throughout the experiments.

ELASTICITY AND PLASTICITY

84-1811

Endochronic Theory of Dynamic Viscoplasticity

H.C. Lin

Argonne Natl. Lab., IL, Rept. No. ANL-83-59, 24 pp (June 1983)
DE83017531

Key Words: Plasticity theory

This report summarizes the work completed on a project concerned with engineering models in dynamic plasticity. The concept of the endochronic theory of viscoplasticity and its subsequent improvement are discussed briefly. Applications and extensions of the theory to various dynamic problems are presented. In particular, the strain-rate effect in the improved endochronic theory and its application to wave propagation problems are discussed.

84-1812

Finite Oscillation of Viscoelastic Cantilever Strip

A. Mioduchowski, A. Pielorz, W. Nadolski, and J.B. Haddow

Univ. of Alberta, Edmonton, Alberta T6G 2G8, Canada, Acta Mech., 50 (1/2), pp 39-48 (1983) 7 figs, 8 refs

Key Words: Cantilever beams, Viscoelastic properties, Free vibration, Large amplitudes, Galerkin method

Large amplitude free vibration of an inextensible initially straight thin viscoelastic cantilever, which is released from rest, from a relaxed deflected form is analyzed. The cantilever, which is a thin strip of rectangular cross section is assumed to be composed of standard viscoelastic material. Although large deflections and rotations are considered the strains are small so that linear viscoelastic theory can be incorporated into a nonlinear bending theory. It is shown how approximate solutions can be obtained using Galerkin's method.

84-1813

A Simplified Viscoelastic Constitutive Equation Applied to a Dynamic Finite Deformation Problem

R.J. Tair, J.B. Haddow, and T.B. Moodie

Univ. of Alberta, Edmonton, Alberta, Canada, Intl. J. Nonlin. Mech., 19 (1), pp 11-18 (1984) 2 figs, 5 refs

Key Words: Constitutive equations, Viscoelastic properties

A single integral type of constitutive equation for finite viscoelastic deformation is proposed. A special case, which is a viscoelastic generalization of the constitutive equation for a neo-Hookean elastic solid, is used to consider the finite deformation problem of shock wave propagation resulting from the sudden application of compressive force at the end of a semi-infinite viscoelastic bar. An approximate method is used to determine the shock front path and shock strength when the viscoelastic dissipative effect is small.

WAVE PROPAGATION

(Also see Nos. 1696, 1777, 1849)

84-1814

SH Waves Due to a Point Source in an Inhomogeneous Medium

A. Chattopadhyay, A.K. Pal, and M. Chakraborty

Indian School of Mines, Dhanbad -- 826004, India, Intl. J. Nonlin. Mech., 19 (1), pp 53-60 (1984) 4 figs, 5 refs

Key Words: Elastic waves, Wave propagation, Point source excitation

The propagation of SH waves due to a point source in an homogeneous medium lying over an inhomogeneous substratum is investigated. The Green's function technique developed by Ghosh is used to solve the problem.

84-1815

Linear Inviscid Wave Propagation in a Waveguide Having a Single Boundary Discontinuity: Part I: Theory

C. Thompson

Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Acoust. Soc. Amer., 75 (2), pp 346-355 (Feb 1984) 6 figs, 12 refs

Key Words: Wave propagation

An examination of wave propagation in waveguides of rectangular cross section having a single boundary discontinuity is presented. Special attention is paid to waveguides with heights that are small compared to an acoustic wavelength. It is shown that the dynamic behavior of the enclosed fluid can be parametrized by the value of a single small parameter ϵ, where ϵ is the ratio of the typical duct height H_0 to the wall wavelength L_0. The influence of planar discontinuities of zero and small but finite thickness on wave propagation is determined using the method of matched asymptotic expansions. Junction conditions, impedance across the junction, and uniformly valid composite expansions for the pressure in the duct are presented.

84-1816

Linear Inviscid Wave Propagation in a Waveguide Having a Single Boundary Discontinuity: Part II: Application

C. Thompson

Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Acoust. Soc. Amer., 75 (2), pp 356-362 (Feb 1984) 7 figs, 5 refs

Key Words: Wave propagation, Sound waves

The method of match asymptotic expansions is used to analyze wave propagation in two problem geometries. The acoustic pressure is evaluated for a waveguide having a single discontinuity in wall slope and a waveguide having a right-angle bend. A two-part representation of the fluid motion across the discontinuity for each problem is tabulated. A uniformly valid expression for the pressure for each problem is given.

84-1817

Propagation of Shock Waves at the Surface of Heterogeneous Soil Grounds

U. Holzlöhner and L. Auersch

Bundesanstalt für Materialprüfung (BAM), Berlin, W. Germany, Intl. J. Numer. Anal. Methods Geomech., 8 (1), pp 57-70 (Jan/Feb 1984) 9 figs, 1 table, 23 refs

Key Words: Shock waves, Wave propagation, Soils

The paper deals with the propagation of shock waves at the surface of soils. Heterogeneity and damping are introduced into analytical half-space solutions. The suggested model explains two phenomena, often observed with shock propagation in actual soils, that differ from the behavior of the homogeneous half-space: the pronounced decay of the disturbances with distance and the elongation of the disturbance into a train of waves. The effects of heterogeneity and damping are discussed quantitatively.

84-1818

Scattering by a Cylinder: A Fast Exact Numerical Solution

N.N. Bojarski

16 Pine Valley Lane, Newport Beach, CA 92660, J. Acoust. Soc. Amer., 75 (2), pp 320-323 (Feb 1984) 6 figs, 8 refs

Key Words: Sound waves, Electromagnetic waves, Wave scattering, Cylinders, Numerical analysis

The known exact analytic solutions to the problem of (acoustic and electromagnetic) scattering by a two-dimensional infinite right circular cylinder are not in closed form, but consist of infinite series, each term of which contains Hankel and Bessel functions of increasing order, and the convergence rate of which decreases rapidly with increasing (ka) numbers. For a given numerical solution, it is thus necessary to compute many Hankel and Bessel functions in high order for each spatial datum point for which the scattered field need be calculated. Presented is an exact numerical method of solution, which is in closed form, and requires the computation of only one Hankel function of order unity per spatial datum point for which the fields need be calculated. The method consists of a closed form numerical deconvolution solution of the scattering integral equation, executed efficiently with the aid of the fast Fourier transform algorithm.

gram is computed. The computation is performed using a VAX 11/780 mainframe computer in combination with an FPS AP-120B floating point array processor. All input, output and intermediate data is stored on RP06 disk drives. This report presents an evaluation of computation time, AP-120B array processor memory requirements and disk storage requirements as a function of N = PxQ and M, the number of frequency cells to be analyzed.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

(Also see Nos. 1608, 1609, 1716, 1857, 1858)

84-1819

Design Principles for Integrating Sound Level Meters

P. Hedegaard

Tech. Rev. (B&K), (4), pp 24-33 (1983) 7 figs, 2 refs

Key Words: Sound level meters

Several methods may be used for direct measurement and calculation of the equivalent continuous sound pressure level, L_{eq}. From the measuring application, desired measuring accuracy, speed as well as the cost frame for the actual design, the instrument designer has to select his circuits and decide on the compromises necessary. Practical examples of direct measuring/calculating methods used, including their advantages and disadvantages, are given. Two test methods and their influence on judgment of the quality of different instrument designs are illustrated.

84-1820

Timing and Memory Sizing Study for Wavenumber Analyzer

R.W. Zaorski, J. Dolansky, and B.E. McCann

Dynatron Corp., Waltham, MA, Rept. No. DARPA Order-4462, 39 pp (Dec 5, 1983)

AD-A135 581

Key Words: Wave analyzers, Frequency analyzers, Hydrophones, Underwater sound

Frequency-wave number analysis is performed on data from a PxQ element hydrophone array. The array is mapped onto a plane, a sector of a sphere or a sector of a cylinder. A 3-dimensional frequency-wave number, averaged spectro-

84-1821

Double Resonator Cantilever Accelerometer

D.R. Koehler

Dept. of Energy, Washington, DC, U.S. Patent Application No. 6-422 515, 15 pp (Sept 23, 1982)

· DE83018057

Key Words: Accelerometers

A digital quartz accelerometer includes a pair of spaced double-ended tuning forks fastened at one end to a base and at the other end through a spacer mass. Transverse movement of the resonator members stresses one and compresses the other, providing a differential frequency output which is indicative of acceleration.

84-1822

Preliminary Results of the First Static Calibration of the RSRA Helicopter Active-Isolator Rotor Balance System

C.W. Acree, Jr.

NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. A-9457, NASA-TM-84395, 260 pp (Nov 1983)

N84-13178

Key Words: Measuring instruments, Aerodynamic loads, Helicopters

The helicopter version of the Rotor Systems Research Aircraft (RSRA) is designed to make simultaneous measurements of all rotor forces and moments in flight analogous to a wind tunnel balance. Loads are measured by a combination of load cells, strain gages, and hydropneumatic active isolators which use pressure gages to measure loads. Complete evaluation of the system performance required calibration of the rotor force and moment measuring system when installed in the aircraft. Measurement system responses to rotor loads obtained during the first static calibration of the RSRA helicopter are plotted and discussed. Plots of the raw transducer data are included.

84-1823

Measurement of Impact Loads Between Curved Contact Surfaces (Messtechnisches Bestimmen stossartiger Belastungen zwischen gekrümmten Kontaktflächen)

J. Müller, W. Kaminsky, and D. Troppens

Wilhelm-Pieck-Universität Rostock, Sektion Landtechnik, German Dem. Rep., Maschinenbautechnik, 33 (2), pp 52-56 (1984) 13 figs, 10 refs

(In German)

Key Words: Measuring instruments, Impact force

A newly developed patented piezoelectric pick-up for the measurement of loading, especially impact loading, between curved impact surfaces is discussed. The measurement technique and results are demonstrated in a determination of contact forces at the roller chain-sprocket wheel location.

84-1824

Improvements of Laser Interferometric Measurement System of Vibration Displacements

T. Adachi, M. Okazaki, and Y. Tsuzuki

Yokohama National Univ., Yokohama, Japan, Proc. of Annual Symp. on Frequency Control (37th), June 1-3, 1983, Marriott Hotel, Philadelphia, PA, pp 187-193 (AD-A 136 673)

AD-P002 475

Key Words: Quartz crystals, Resonators, Interferometric techniques

Improvements were made on the laser interferometric measurement system of vibration displacements of quartz crystal resonators. The DC phase control and the small-deviation low-frequency phase modulation are introduced on a laser beam. The amplitude of the vibration displacement is obtained as a digital data. A measurement and processing of data are made by the computer system. The improved system can be used to the measurement of vibration displacement down to five angstroms within a few percent repeatability in the frequency range from 1 MHz to 10 MHz.

84-1825

Investigations in Short-Range Seismic Propagation

R.F. Powell and M.R. Clay

Royal Military College of Science, Shrivenham, Wiltshire, UK, J. Low Frequency Noise Vib., 2 (1), pp 12-19 (1983) 9 figs, 5 refs

Key Words: Measurement techniques, Measuring instruments, Seismic waves, Wave propagation

The detection and location of a low-frequency seismic source is an increasingly significant environmental problem which is made more difficult by the complex nature of a seismic signal and the effect on it of ground transmission. The topic is discussed here in the context of augmenting a conventional undergraduate course in introductory waves and vibrations. Investigations are made of the geophone as a detector, the problem of seismic noise, the variation of seismic signatures with range and their interpretation, and a simple array for source direction.

84-1826

Fast AR and ARMA Modelling and Spectrum Analysis

I.O. Pandelidis

Ph.D. Thesis, Univ. of Wisconsin-Madison, 211 pp

DA8323396

Key Words: Spectrum analysis, Mathematical models

New methods for fast AR and ARMA parameter and spectrum estimation are proposed for on-line application. An on-line microprocessor-based ARMA spectrum analyzer is also implemented incorporating the fast estimation methods.

84-1827

Study on the Fluidelastic Vibration of Tube Arrays Using Modal Analysis Technique

K. Ohta, K. Kagawa, H. Tanaka, and S. Takahara

Nagasaki Technical Inst., Technical Headquarters, Mitsubishi Heavy Industries, Ltd., Nagasaki City, Japan, J. Pressure Vessel Tech., Trans. ASME, 106 (1), pp 17-24 (Feb 1984) 14 figs, 13 refs

Key Words: Modal analysis, Tube arrays, Heat exchangers, Fluid-induced excitation

A method is presented to calculate the critical flow velocity of fluidelastic vibration of tube arrays in heat exchangers. The method is based upon the modal analysis technique, which combines the fluid dynamic force caused by cross flow and the vibration characteristics of the complicated tube array to obtain its response. The analytical method enables one not only to take into account the vibration mode of tube array and nonuniformity of velocity and density distribution of cross flow, but also to estimate the effect of antivibration devices, such as spacer, connecting band, etc.

84-1828

Using Modal Analysis to Improve Confidence in Finite Element Analysis

M. Good and D. Macioce

Structural Measurement Systems, Inc., San Jose, CA, S/V, Sound Vib., 18 (1), pp 18-22 (Jan 1984) 6 figs, 6 tables, 5 refs

Key Words: Modal analysis, Experimental modal analysis, Finite element technique

A method is demonstrated for improving the correlation of dynamic analysis results from modal testing and finite element analysis. The method is based on a perturbation of the joint properties of the structure within the finite element model and maximizing a calculated correlation coefficient between the two sets of eigenvalues and eigenvectors.

84-1829

Dual Correlated Random Excitation Technique for Modal Testing

M. Sano, T. Kai, and K. Komatsu

National Aerospace Lab., Tokyo, Japan, Rept. No. NAL/TR-762, 13 pp (1983)
PB84-138072
(In Japanese)

Key Words: Experimental modal analysis, Random excitation

A dual correlated random excitation technique is presented for estimating the modal parameters of symmetric structures. In this procedure, a pure random signal is used to drive each of two identical excitation systems located at symmetric positions of the structure in order to reduce the number of degrees of freedom in a given measurement by separating symmetric and anti-symmetric vibration modes.

84-1830

Ratio Calibration -- the Right Choice for Modal Analysis

D. Corelli

Quixote Measurement Dynamics, Inc., Cincinnati, OH, S/V, Sound Vib., 18 (1), pp 27-30 (Jan 1984) 7 figs

Key Words: Experimental modal analysis

In order to get calibrated inertance frequency response measurements for modal analysis tests, it is not necessary to know the individual transductances of the accelerometer and force transducer. If the ratio of the transductances is known, it can be used to convert dimensionless frequency response measurements directly into engineering units without requiring intermediate computations of acceleration and force. This article describes ratio calibration, a generative calibration process for measuring the transductance ratio function for an accelerometer/force transducer pair. It is a simple test that can be performed during equipment setup for a structural dynamics test.

84-1831

Determination of Transmission Loss, Acoustic Velocity, Surface Velocity and Radiation Efficiency by Use of Two Microphone Techniques

B.H. Forssen

Ph.D. Thesis, Purdue Univ., 226 pp (1983)
DA8400354

Key Words: Panels, Sound transmission loss, Two microphone technique

This thesis is concerned with the development of novel measurement approaches to estimate surface velocity, radiation efficiency and transmission loss of panel structures. These approaches are based on the estimates of the auto and cross spectral densities of the sound pressures measured by two closely spaced microphones. Some of these approaches involve the use of the recently developed two microphone acoustic intensity technique, which is reviewed extensively.

84-1832

Temperature Derivatives of Elastic Stiffnesses Derived from the Frequency-Temperature Behavior of Quartz Plates

P.C.Y. Lee and Y.K. Yong

Dept. of Civil Engrg., Princeton Univ., NJ, Proc. of Annual Symp. on Frequency Control (37th), June 1-3, 1983, Marriott Hotel, Philadelphia, PA, pp 200-207 (AD-A136 673)
AD-P002 477

Key Words: Temperature effects, Plates, Quartz crystals

Linear field equations for small vibrations superposed on thermally induced deformations by steady and uniform temperature changes are derived from the nonlinear field equations of thermoelasticity in Lagrangian formulation. From the solutions of these equations for the thickness-vibrations, the temperature derivatives of elastic stiffnesses are related analytically to the known or measured properties such as the second and third order elastic stiffnesses, thermal expansion coefficients, and temperature coefficients of frequency of quartz plates.

DYNAMIC TESTS

84-1833
Design Considerations of Platens for Vibration Testing
L.J. Lipp
Product Assurance Directorate, Army Armament Res. and Dev. Command, Dover, NJ, Rept. No. ARPAD-TR-83003, SBI-AD-E401 110, 43 pp (Nov 1983)
AD-A135 815

Key Words: Vibration tests, Test facilities

Vibration testing, particularly when performed in reliability test chambers, is very costly. Discussed in this report are design considerations for a vibration test platen which will accept several test specimens for simultaneous testing. Well designed platens will provide more meaningful results and reduce test time and costs through maximum utilization of test hardware. Specific points covered are: bending modes at the platen's frequency; determining the resonant frequency of a test platen; determining the damping energy of a platen design; obtaining signal feedback for vibration control purposes; deriving equations for resonant frequencies and damping energies.

84-1834
Least Favorable Response of Inelastic Structures
F.C. Chang, T.L. Paez, F. Ju
Bureau of Engrg. Res., Univ. of New Mexico, Albuquerque, NM, Rept. No. CE-63(83)AFOSR-993-1, AFOSR-TR-83-1226, 58 pp (Mar 1983)
AD-A136 289

Key Words: Dynamic tests, Testing techniques, Least favorable response method

In the design of a structural system, a test input is sought to conservatively represent an ensemble of measured field inputs. When a structure survives the test input, it is assumed that it would survive the field inputs. The method of shock response spectra is a technique for specifying conservative test inputs, but it has some disadvantages. In this investigation a technique is developed for the specification of test inputs. It is based on the method of least favorable response, and it overcomes some of the shortcomings of the method of shock response spectra.

84-1835
New Operation Method for a Large-Scale Shock Tunnel
K. Soga, Y. Inoue, and T. Yamazaki
National Aerospace Lab., Tokyo, Japan, Rept. No. NAL-TR-765, 14 pp (1983)
N84-13200
(In Japanese)

Key Words: Dynamic tests, Shock tests, Test facilities, Shock tubes

In order to construct and operate a large-scale shock tunnel for use in such projects as the recovery of rocket payloads and artificial satellites, a new operational method for short-duration wind tunnels using a large-orifice plate and high speed valves is proposed. The practicability of this method was studied using the gun tunnel, and the results of these experiments are shown. The measurements of the tunnel stagnation pressure and temperature changing the orifice area with and without a piston; performance test of the high speed valve installed in front of the nozzle; and measurements of pitot pressure and stagnation heat-transfer rate of the cylinder to diagnose the flow established in the test section are provided.

DIAGNOSTICS

(Also see No. 1870)

84-1836
Acoustic Emission Determination of Deformation Mechanisms Leading to Failure of Naval Alloys. Volume 1
J.T. Glass, S. Majerowicz, and R.E. Green, Jr.
Dept. of Materials Science and Engrg., Johns Hopkins Univ., Baltimore, MD, Rept. No. DTNSRDC/SME-CR-18-83, 163 pp (May 1983)
AD-A135 387

Key Words: Diagnostic techniques, Acoustic emission, Failure detection, Steel

The acoustic emission behavior of three Naval alloy steels (HY 80, HY 100 and HY 130) was characterized during tensile elongation and bend type loading. The detection of emissions was accomplished using a very new, state of the art interferometer as well as with a unique piezoelectric transducer. The deformation and fracture of these HY steels was documented via optical and scanning electron microscopy and was correlated with observed emissions in order to determine the generating mechanisms.

84-1837

Acoustic Emission Determination of Deformation Mechanisms Leading to Failure of Naval Alloys. Volume 2

J.T. Glass, S. Majerowicz, and R.E. Green, Jr.

Dept. of Materials Science & Engrg., Johns Hopkins Univ., Baltimore, MD, Rept. No. DTNSRDC/SME-CR-19-83, 258 pp (May 1983)

AD-A135 388

Key Words: Diagnostic techniques, Failure detection, Measuring instruments, Acoustic emission

An experimental investigation was conducted to determine the degree of acoustic emission signal modification due to propagation through specimens of different geometries. Initial efforts were directed at comparison of a number of acoustic emission probes in order to determine their sensitivity and their ability to detect an unmodified reproducible theoretically predicted waveform.

84-1838

Elastic-Wave Inverse Scattering in Non-Destructive Evaluation

J.H. Rose

Ames Lab., IA, Rept. No. IS-M-433, 16 pp (1983)

DE83017683

Key Words: Diagnostic techniques, Failure detection, Testing techniques, Elastic waves, Wave scattering

Ultrasonic detection and characterization of flaws in metals and ceramics is of considerable technological interest. Scattering and inverse scattering theories have recently been applied to these tasks in a systematic manner and considerable progress has resulted. The development of scattering and inverse scattering methods in the AF/DARPA Program in Quantitative Non-Destructive Evaluation is reviewed briefly and the inverse Born approximation method is discussed in detail. Progress is reviewed and the ability of the method to distinguish volumetric and crack-like flaws is demonstrated in simple cases.

84-1839

Detection of Closed Internal Fatigue Cracks

B.R. Tittmann, L. Ahlberg, O. Buck, F. Cohen-Tenoudji, and G. Quentin

Science Ctr., Rockwell International, Thousand Oaks, CA, Rept. No. IS-M-443 (Pres. at the Conf. on Nondestructive Testing, Santa Cruz, CA, Aug 1983), CONF-830811-3, 12 pp (1983)

DE83017686

Key Words: Diagnostic techniques, Failure detection, Ultrasonic techniques, Testing techniques

This paper reviews some recent work on the detection and sizing of closed internal fatigue cracks by ultrasonic techniques. Major emphasis is put on the diffraction of shear waves at the crack tip. Both fully open as well as partially closed cracks were considered. The effect of crack closure stress on back-scattered (pulse-echo) shear waves was studied with the aid of an Al compact tension specimen. Noticeable changes with crack closure stress were documented for the structure of both the time-domain and frequency-domain representations.

84-1840

Measurements of Ultrasonic Scattering from Near-Surface Flaws

D.K. Hsu, T.A. Gray, and R.B. Thompson

Ames Lab., IA, Rept. No. IS-M-447 (Pres. at the Conf. on Quantitative Nondestructive Testing, Santa Cruz, CA, Aug 1983), CONF-830811-2, 19 pp (1983)

DE83017693

Key Words: Failure detection, Diagnostic techniques, Ultrasonic techniques, Testing techniques

In ultrasonic NDE measurements the detection of subsurface flaws is of practical importance, especially flaws too far from the surface to be detected by eddy-current methods and yet close enough to the surface for the flaw-surface interaction to be important. Experimental results of ultrasonic scattering measurements of subsurface flaws in the presence of a fluid-solid interface are reported and compared with theoretical calculations of subsurface flaw scattering.

Comparison of the absolute value of the scattering amplitude in terms of frequency, flaw-to-surface distance, ultrasonic mode and scattering angle is made for an oblate spheroidal void in the interior of bulk titanium and for a spherical inclusion near the surface of a thermoplastic sample.

84-1841

Vibration Produced by a Single Point Defect on the Inner Race of a Rolling Element Bearing under Radial Load

P.D. McFadden and J.D. Smith
Dept. of Engrg., Cambridge Univ., UK, Rept. No. CUED/C-MECH/TR-32-1983, 36 pp (1983)
PB84-139617

Key Words: Diagnostic techniques, Rolling contact bearings

A model is developed to describe the vibration produced by a single point defect on the inner race of a rolling element bearing under constant radial load. The model incorporates the effects of bearing geometry, shaft speed, bearing load distribution, transfer function and the exponential decay of vibration. A comparison of predicted and measured demodulated vibration spectra confirms the satisfactory performance of the model.

MONITORING

84-1842

Implementing the High-Frequency Resonance Technique for the Vibration Monitoring of Rolling Element Bearings

P.D. McFadden and J.D. Smith
Dept. of Engrg., Cambridge Univ., UK, Rept. No. CUED/C-MECH/TR-31-1983, 34 pp (1983)
PB84-140003

Key Words: Monitoring techniques, Bearings, Rolling contact bearings

Some important practical aspects of implementing the high-frequency resonance technique for the vibration monitoring of rolling element bearings are discussed, including the performance characteristics of the band-pass filter, the design of the rectifier and smoothing circuits, and the method of spectral analysis.

84-1843

Acoustic Emission Transducers for the Vibration Monitoring of Bearings at Low Speeds

P.D. McFadden and J.D. Smith
Dept. of Engrg., Cambridge Univ., UK, Rept. No. CUED/C-MECH/TR-29-1983, 20 pp (1983)
PB84-139526

Key Words: Monitoring techniques, Bearings, Acoustic emission

The use of acoustic emission transducers for the vibration monitoring of rolling element bearings at low speeds is explored. The frequency response and the base strain and bending sensitivities of the transducers are shown to be important parameters.

84-1844

Vibration Monitoring of Rolling Element Bearings by the High-Frequency Resonance Technique: A Review

P.D. McFadden and J.D. Smith
Dept. of Engrg., Cambridge Univ., UK, Rept. No. CUED/C-MECH/TR-30-1983, 47 pp (1983)
PB84-139591

Key Words: Monitoring techniques, Rolling contact bearings, Bearings, High frequency resonance technique

The high frequency resonance technique for the vibration monitoring of rolling element bearings is reviewed. It is shown that the procedures for obtaining the spectrum of the envelope signal are well established, but that there is an incomplete understanding of the factors which control the appearance of this spectrum. Until the envelope spectrum can be fully explained, use of the technique is limited.

84-1845

Transducer Selection for Vibration Monitoring of Rotating Machinery

M. Gilstrap
Bently Nevada Corp., Minden, NV, S/V, Sound Vib., 18 (2), pp 22-24 (Feb 1984) 2 figs

Key Words: Monitoring techniques, Transducers, Rotating machinery

Selecting the proper transducer for monitoring vibration on rotating machinery can be difficult. A variety of transducers is available - proximity probes, shaft riders, dual probes, velocity transducers, and accelerometers. This article discusses the pros and cons of making vibration measurements on the shaft and bearing housing as well as making vibration measurements relative to the bearing and free space. Economic considerations, potential machine problems, vibration characteristics, and other factors that influence the selection of transducers are also discussed.

84-1846
How to Develop a Machinery Monitoring Program
J.S. Mitchell
Palomar Technology International, Inc., Carlsbad, CA, S/V, Sound Vib., 18 (2), pp 14-20 (Feb 1984) 10 figs, 4 refs

Key Words: Monitoring techniques

Over the past decade, machinery condition monitoring has become a generally accepted practice whose advantages are well documented. As with most technology, condition monitoring embraces a broad variety of methods and measurements for which no single article can provide complete detail. What can be accomplished, however, is to view monitoring from an overall perspective and to provide guidance in a number of areas. This article attempts to meet this objective by examining three areas: the considerations involved in establishing an effective monitoring program; a survey of some of the accepted methods of monitoring; and suggested improvements that can be made through innovative use of modern electronic technology.

84-1847
Techniques of Condition Monitoring and Fault Diagnosis in Industry
L.X. Nepomuceno
Laboratorio de Acustica e Sonica, Sao Paulo, Brazil, 159 pp (1983) (Pres. at the Seminar Intern. De Manutecao, Sau Paulo, Brazil, Aug 23-25, 1983) N84-13595
(In Portuguese)

Key Words: Monitoring techniques, Industrial facilities

The philosophy of condition monitoring in industry, through the measurement, control and monitoring of some adequate parameters, such as temperature, pressure, oil analysis, a visual examination, measurement and analysis of vibration in terms of displacement, velocity or acceleration depending on the case is presented. Some fundamental ideas of non-destructive testing techniques that are important for an effective maintenance program, and some ideas of the most modern nonconventional processes are presented.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

84-1848
A Generalized Dunkerley-Graeffe Procedure for Complex Vibrating Systems
S.A. Paipetis
Univ. of Patras, Patras, Greece, J. Sound Vib., 92 (2), pp 173-180 (Jan 22, 1984) 2 figs, 5 tables, 14 refs

Key Words: Eigenvalue problems, Complex modes

The combined use of the principle underlying Dunkerley's rule for the approximate determination of the gravest eigenfrequency of a multi-degree-of-freedom elastic system and of the root-squaring process suggested by Graeffe provide a generalized procedure for the approximate solution of complex frequency equations; i.e., for the determination of any number of eigenvalues at the desired accuracy level, provided that the eigenfunctions involved can be expressed in series expansion. By simple algebraic means, the method yields solutions in cases for which sophisticated computing facilities would otherwise be necessary and provides the means for checking complicated computer outputs as well as approximate results for preliminary design purposes.

84-1849
Stress Waves in an Elastic Half-Space: Single and Multiple Surface Sources
B.W. Stump
U.S. Air Force, Air Force Weapons Lab., NTES, Kirtland Air Force Base, NM 87117, J. Sound Vib., 92 (2), pp 181-201 (Jan 22, 1984) 21 figs, 28 refs

Key Words: Elastic half-space, Wave propagation, Stress waves, Explosion effects

The displacement vector and the stress tensor in an elastic half-space subjected to a point force load on the free surface is calculated by using the method of Cagniard and de Hoop. The stresses are calculated at depth and arrivals include the P, S, PS diffracted (von Schmidt wave), Rayleigh, and near field components of motion. These point force results are extended to multiple sources in triangular and hexagonal spacing.

84-1850

The Solution of Higher Order Integration Formulae for Dynamic Response Equations by the Conjugate Gradient Method

A.L. Carter, G.R. Shiflett, and A.J. Laub

Holmes & Narver, Inc., Orange, CA, Intl. J. Numer. Methods Engrg., 20 (2), pp 339-351 (Feb 1984) 9 figs, 2 tables, 9 refs

Key Words: Conjugate gradient method

Higher order implicit integration techniques for solving dynamic response equations are derived utilizing Padé approximations. In an effort to minimize the disadvantages of using these higher order formulae to obtain solutions to systems with large numbers of degrees-of-freedom, the conjugate gradient method is employed to solve for the displacements. The accuracy and efficiency of the techniques are evaluated by making comparisons between known analytical and calculated results.

84-1851

Eigenvalues and Stable Time Steps for the Uniform Strain Hexahedron and Quadrilateral

D.P. Flanagan and T. Belytschko

Sandia Labs., Albuquerque, NM, J. Appl. Mech., Trans. ASME, 51 (1), pp 35-40 (Mar 1984) 2 figs, 8 refs

Key Words: Eigenvalue problems

Simple formulas for bounding the maximum eigenvalues or computing them exactly are obtained for the uniform strain eight-node hexahedron and the four-node quadrilateral. The development is based on a novel technique that reduces the size of the eigenproblem to where it can be managed analytically. These formulas are useful for explicit time integration applications since they provide conservative estimates of stable time steps.

84-1852

Input-Output Matching in Linear Mechanical Systems

W. Gawronski

Inst. of Fluid Flow Machinery, Polish Academy of Sciences, ul. Fiszera 14, 80-952 Gdansk, Poland, J. Sound Vib., 92 (4), pp 569-581 (Feb 22, 1984) 5 figs, 2 tables, 13 refs

Key Words: Linear systems, Harmonic response

The steady state forced harmonic motion of a linear mechanical system is considered. The application of the matching method to the identification of unknown system matrices, and hence to shifting a system resonance frequency, is presented. Three practical methods of achieving input-output matching are proposed.

84-1853

Vibration of a Homogeneous Half-Space of Arbitrary Poisson's Ratio Interrupted by a Frictionless Plane

A.O. Awojobi

Univ. of Lagos, Nigeria, Intl. J. Numer. Anal. Methods Geomech., 8 (1), pp 45-55 (Jan/Feb 1984) 2 figs, 3 refs

Key Words: Half-space, Vibration analysis, Harmonic response, Hankel transformation

The work presents an exact expression for the Hankel transform of the surface displacement or a rigid circular body performing harmonic vertical vibrations on a homogeneous elastic half-space of arbitrary Poisson's ratio interrupted at some depth by a frictionless horizontal plane.

MODELING TECHNIQUES

84-1854

Aeroelastic Analysis Using Nonlinear Aerodynamic Methods

E.H. Dowell

Princeton Univ., NJ, Rept. No. AFOSR-TR-83-0896, 4 pp (Aug 1983)
AD-A135 133

Key Words: Mathematical models, Aerodynamic loads

An extended nonlinear indicial approach to modeling nonlinear aerodynamic forces for aeroelastic analyses has been developed. The basic approach is based upon describing function ideas.

84-1855

Mathematical Models for Damageable Structures

M.L. Wang, T.L. Paez, and F. Ju

Bureau of Engrg. Res., Univ. of New Mexico, Albuquerque, NM, Rept. No. CE-64(83)AFOSR-993-1, AFOSR-TR-83-1256, 91 pp (Mar 1983)

AD-A136 574

Key Words: Mathematical models, Blast response

The reliability of a structural system at a particular time depends on the damage level in the system. When the damage level exceeds a critical value, then failure occurs. In the present investigation some basic models are proposed for the study of damageable structure response. The models are a higher order linear differential equation with constant coefficients and a second order linear differential equation with time varying coefficients.

NUMERICAL METHODS

84-1856

Dynamic Behaviour of Saturated Porous Media; The Generalized Biot Formulation and Its Numerical Solution

O.C. Zienkiewicz and T. Shiomi

University College of Swansea, Swansea, UK, Intl. J. Numer. Anal. Methods Geomech., 8 (1), pp 71-96 (Jan/Feb 1984) 13 figs, 2 tables, 64 refs

Key Words: Porous materials, Biot theory, Numerical analysis, Seismic waves

The basic equations of motion for porous media were established by Biot, and despite many subsequent rederivations, are, with minor modificatons, relevant today. However, some changes of variables and approximations are on occasion useful, and this paper discusses the alternative forms available and their relative efficiency of solution in the numerical context. Here penalty methods prove once again useful. The paper is illustrated with examples covering phenomena of different periods ranging from shock excitation to slow consolidation which are treated in a single unified program.

PARAMETER IDENTIFICATION

84-1857

Maximum Likelihood Estimates of Linear Dynamic System Parameters

T.G. Ryall

Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL-STRUC-395, 22 pp (Jan 1983)

AD-A136 400

Key Words: System identification techniques, Maximum likelihood method

The parameters of a linear dynamic system are estimated using the maximum likelihood method. Maximum likelihood estimates are asymptotically unbiased and efficient. Two different situations are studied: random excitation force and deterministic excitation force.

DESIGN TECHNIQUES

84-1858

An Efficient Method to Predict the Effect of Design Modifications on the Dynamics of Structures

H.M. Rizai

Ph.D. Thesis, Michigan State Univ., 98 pp (1983)

DA8400618

Key Words: Design techniques, Structural modification techniques

An efficient method is presented to predict the effect of design modifications on mechanical and structural systems with a large number of degrees of freedom. The method minimizes a cost function which includes natural frequencies, size of design change and the static deflections. It uses a finite element preprocessor to find derivatives of mass and stiffness matrices and computationally efficient techniques to find eigenvalue and eigenvector derivatives.

COMPUTER PROGRAMS

84-1859

Experience in Using a Finite Element Stress and Vibration Package on a Minicomputer

S.P. Penniment

Advanced Engrg. Lab., Adelaide, Australia, 18 pp (1982) (Proc. of ACADS National CAD/CAM Conf. Held at COMTEC '82)
AD-A135 611

Key Words: Computer programs, Finite element technique

The use of a finite element analysis package running on an in-house PDP 11/60 minicomputer is described. Case studies are presented to illustrate the approach taken to problems involving stress level and deflection estimation and free vibration analysis.

Rept. No. UTRC83-6, NASA-CR-3729, 255 pp (Dec 1983)
N84-12530

Key Words: Propellers, Computer programs

Mathematical development is presented for a specialized propeller dedicated version of the G400 rotor aeroelastic analysis. The G400PROP analysis simulates aeroelastic characteristics particular to propellers such as structural sweep, aerodynamic sweep and high subsonic unsteady airloads (both stalled and unstalled). Formulations are presented for these expanded propeller related methodologies. Results of limited application of the analysis to realistic blade configurations and operating conditions which include stable and unstable stall flutter test conditions are given.

84-1860

NASTRAN Flutter Analysis of Advanced Turbopropellers

V. Elchuri and G.C.C. Smith
Bell Aerospace Textron, Buffalo, NY, Rept. No. D2536-941009, NASA-CR-167926, 121 pp (Apr 1982)
N84-14148

Key Words: NASTRAN (computer program), Flutter, Modal analysis, Turbofan engines, Propellers

An existing capability developed to conduct modal flutter analysis of tuned bladed-shrouded discs in NASTRAN was modified and applied to investigate the subsonic unstalled flutter characteristics of advanced turbopropellers. The modifications pertain to the inclusion of oscillatory modal aerodynamic loads of blades with large (backward and forward) variable sweep. The two dimensional subsonic cascade unsteady aerodynamic theory was applied in a strip theory manner with appropriate modifications for the sweep effects. Each strip is associated with a chord selected normal to any spanwise reference curve such as the blade leading edge. The stability of three operating conditions of a 10-bladed propeller is analyzed.

84-1861

Aeroelastic Analysis for Propellers - Mathematical Formulations and Program User's Manual

R.L. Bielawa, S.A. Johnson, R.M. Chi, and S.T. Gangwani
United Technologies Res. Ctr., East Hartford, CT,

84-1862

Examples in the Use of the Finite Element Library: Free Vibration of an Elastic Solid

C. Greenough and K. Robinson
Rutherford Appleton Lab., Science and Engrg. Res. Council, Chilton, UK, Rept. No. RL-82-062, 30 pp (1982)
PB84-144658

Key Words: Computer programs, Finite element technique, Natural frequencies, Mode shapes, Rectangular bodies

The library, a collection of software written to accommodate the growth of finite element techniques, is in two levels: one consists of subroutines which perform most of the basic steps required in a finite element analysis; the other comprises example programs in various application areas. This report deals with dynamic analysis of solids, particularly the calculation of the natural frequencies and the associated mode shapes of a two dimensional rectangular solid. The solid is assumed to be of unit thickness and in a state of plane strain. The report gives details of the theory and the solution of the problem and includes a complete listing of the example program and data.

84-1863

MO678-FUGIT1; Dynamic Response of Elastic Structures

C.M. Friedrich
Bettis Atomic Power Lab., West Mifflin, PA, Mag Tape ANL/NESC-537R (1984)
DE83048537

Key Words: Computer programs, Shock response, Damping effects, Elastic systems, Rigid foundations

FUGIT1 performs a transient step analysis of an elastic structure mounted on a rigid base which has a given shock history of motion. The structure may have nonlinear constraints and damping, 1 to 6 degrees of freedom in the base motion, 1 to 30 rows and columns in the flexibility matrix, 0 to 3 types of damping.

84-1864
M0266; Linear Elastic Structural Dynamics
W.A. Wenzel
Bettis Atomic Power Lab., West Mifflin, PA, Mag Tape ANL/NESC-383R (1984)
DE83048383

Key Words: Computer programs, Shock response

M0266 computes the dynamic shock forces and modal frequencies acting on a lumped mass, linear elastic model of a structure subjected to shock spectrum inputs. The model employed is a collection of lumped masses connected by weightless flexible elements. If the original structure is not statically determinate, redundant forces must be introduced to ensure a primary structure that is. M0266 is limited to a 50 x 50 mass-flexibility matrix.

84-1865
GEM; Eigenvalue Problem for Vibrating Systems
R.L. Fagan and R.B. McCalley
Knolls Atomic Power Lab., Schenectady, NY, Mag Tape ANL/NESC-344R (1984)
DE83048344

Key Words: Computer programs, Eigenvalue problems

GEM is intended primarily to perform vibration studies with the capability of generating input for the VEP (vibration eigenvalue problem) routine and performing additional operations on the output from the SHO (shock) segment. Given a system of masses and springs, the VEP routine computes the natural frequencies of the vibrating system as well as the mode shapes for each frequency. Given the mode shapes, frequencies and masses of a vibrating system, the SHO routine will compute the deflections and forces at the mass points.

84-1866
M0552; Dynamic Analysis of Linear Elastic Systems
E.A. Zanoni
Bettis Atomic Power Lab., West Mifflin, PA, Mag Tape ANL/NESC-283R (1984)
DE83048283

Key Words: Computer programs, Elastic systems

M0552 solves the transient response problem of linear elastic, lumped-mass systems subjected to a unidirectional foundation transient that can be either a velocity or acceleration transient. Normal mode theory is used and the input to the program consists of the mode shapes, frequencies, and foundation transient. Element effects are also evaluated as a function of time. Modal damping coefficients may be specified. The total number of points used to describe the transient is limited to 2000. An option is provided to enable specification of a general trigonometric series having up to 20 terms, as the transient. The number of modes and mass points that can be considered is limited to 50.

84-1867
CREEP-PLAST2; Two-Dimensional Inelastic Structural Analysis
J.A. Clinard
Oak Ridge National Lab., TN, Mag Tape ANL/NESC-810R (1984)
DE83048810

Key Words: Computer programs, Plastic deformation, Cyclic loading, Finite element technique

CREEP-PLAST2 is a special-purpose two-dimensional inelastic structural analysis program based on an incremental finite-element method. It is applicable to static and quasi-static loadings of plane structures (in-plane loadings, plane-stress conditions) and axisymmetric structures (axisymmetric loadings). The loadings can consist of combinations of applied forces, pressures, displacements, and/or temperatures. Cyclic as well as monotonic loadings can be treated, and loadings can be proportional or nonproportional.

84-1868
STRAP; Static and Dynamic Structural Analysis
J.A. Dearien and E.D. Uldrich
EG and G Idaho, Inc., Idaho Falls, ID, Mag Tape ANL/NESC-539 (1984)
DE83048539

Key Words: Computer programs, Dynamic structural analysis

The code STRAP (Structural Analysis Package) was developed to analyze the response of structural systems to static and dynamic loading conditions. STRAP-S solves for the displacements and member forces of structural systems under static loads and temperature gradients. STRAP-D will solve numerically a given structural dynamics problem.

84-1869
SHOCK; Dynamic Response of Lumped-Mass Systems
V.K. Gabrielson
Sandia National Labs., Livermore, CA, Mag Tape ANL/NESC-795 (1984)
DE83048795

Key Words: Computer programs, Mass-spring systems, Shock response

SHOCK calculates the dynamic response of a structure modeled as a spring-mass system having one or two degrees of freedom for each mass when subjected to specified environments. The code determines the behavior of each lumped mass (displacement, velocity, and acceleration for each degree of freedom) and the behavior of each spring or coupling (force, shear, moment, and displacement) as a function of time. Two types of models, axial, having one degree of freedom, and lateral, having two degrees of freedom at each mass can be processed. Damping can be included in all models and shock spectrums of responses can be obtained.

GENERAL TOPICS

TUTORIALS AND REVIEWS

(See No. 1567)

CRITERIA, STANDARDS, AND SPECIFICATIONS

84-1870
Damage Analysis (Schadenanalyse)
VDI Directive Series 3822 (Richtlinienreihe VDI 3822), Avail: Beuth Verlag GmbH, Burggrafenstrasse 4-10, 1000 Berlin 30, Germany
(In German)

Key Words: Diagnostic techniques, Standards and codes

Damage occurs in structural components, machinery and all types of instrumentation. This Directive series consists of four parts. Part 1 -- Basics, Concepts, Definitions, Procedure for Analysis; Part 2 -- Damage Caused by Mechanical Excitation; Part 3 -- Damage Caused by Corrosion in Aqueous Media; Part 4 – Detection and Evaluation of Damage Analysis. (Summarized in VDI-Z, 126 (6), Mar 1984.)

84-1871
Noiseless Design, Rotating Structural Components and Their Supports (Larmarm Konstruieren. Rotierende Bauteile und deren Lagerung)
VDI Directive 3720 Section 4 (Richtlinie 3720 Blatt 4), Avail: Beuth Verlag GmbH, Burggrafenstrasse 4-10, 100 Berlin 30, Germany
(In German)

Key Words: Standards and codes, Design techniques, Rotating machinery, Noise reduction

The VDI Directive 3720 Section 4 describes the mechanism of sound generation, transmission and radiation in structural components of rotating machinery and presents recommendations for noise reduction by correct design of components and supports of the machinery. (Summarized in VDI-Z, 126 (6), Mar 1984.)

BIBLIOGRAPHIES

84-1872
Motor Vehicle Suspension Systems: Vibrational Effects and Stability, 1973 - January, 1984 (Citations from Information Services in Mechanical Engineering Data Base)
NTIS, Springfield, VA, 112 pp (Jan 1984)
PB84-857739

Key Words: Suspension systems (vehicles), Bibliographies

This bibliography contains 215 citations concerning the effects of vibration and ride stability, uneven tire wear, and resulting steering difficulties associated with motor vehicle suspension systems. Hydropneumatic leveling, independent suspension, and active suspension systems are discussed. The use of composite materials, such as fiberglass in suspension springs is also presented.

84-1873

Discrete Fourier Analysis Theory and Applications. 1970 - November, 1983 (Citations from the NTIS Data Base)

NTIS, Springfield, VA, 194 pp (Nov 1983)
PB84-852763

Key Words: Discrete Fourier transform, Bibliographies

This bibliography contains 228 citations concerning applications for discrete Fourier analysis. Consideration is given to the properties and effectivenss of discrete Fourier analysis, as well as to methods of computation and generation of discrete Fourier transform pairs. Applications range from frequency or spectrum analysis to solving linear equations to performing multidimensional convolutions.

AUTHOR INDEX

TECHNICAL NOTES

J.R. Kuttler and V.G. Sigillito
Sloshing of Liquids in Cylindrical Tanks
AIAA J., 22 (2), pp 209-311 (Feb 1984) 1 fig, 1 table, 7 refs

M. Baruch
Methods of Reference Basis for Identification of Linear Dynamic Structures
AIAA J., 22 (4), pp 561-564 (Apr 1984) 15 refs

L.A. Bergman and A.L. Hale
Linear System Identification via Poisson Moment Functionals
AIAA J., 22 (4), pp 566-568 (Apr 1984) 10 refs

J.A. Tichy
Effects of Fluid Inertia and Viscoelasticity on the One-Dimensional Squeeze-Film Bearing
ASLE, Trans., 27 (2), pp 164-167 (Apr 1984) 2 figs, 4 refs

D.E. Allen and G. Pernica
A Simple Absorber for Walking Vibrations
Canad. J. Civil Engrg., 11 (1), pp 112-117 (Mar 1984) 6 figs

M.A. Christie and B. Phelps
Fatigue Testing of uPVC Pressure Pipe
Intl. J. Fatigue, 6 (2), pp 125-127 (Apr 1984) 6 figs, 14 refs

V.J.E. Stark and H. Wittmeyer
Equivalence of Damping from Flight Flutter Test Evaluation and Eigenvalue Calculation
J. Aircraft, 21 (2), pp 159-160 (Feb 1984) 2 tables, 9 refs

L.E. Ericsson and J.P. Reding
Analytic Extrapolation to Full-Scale Aircraft Dynamics
J. Aircraft, 21 (3), pp 222-224 (Mar 1984) 3 figs, 16 refs

K.J. Sidorowicz, W.G. Britson, and M.N. Jenkins
Investigation of Improved Welded Attachment Design Criteria Using the Finite Element Method
J. Pressure Vessel Tech., Trans. ASME, 106 (1), pp 110-114 (Feb 1984) 8 figs, 3 tables, 11 refs

D. Hui
Effects of Geometric Imperfections on Large-Amplitude Vibrations of Rectangular Plates with Hysteresis Damping
J. Appl. Mech., Trans. ASME, 51 (1), pp 216-220 (Mar 1984) 3 figs, 1 table, 17 refs

C.H. Chang
On Transverse Membrane Vibration of Conical Shells
J. Appl. Mech., Trans. ASME, 51 (1), pp 213-214 (Mar 1984) 8 refs

B. Banerjee
Large-Amplitude Vibrations of Polygonal Plates – A New Approach
J. Appl. Mech., Trans. ASME, 51 (1), pp 211-213 (Mar 1984) 3 tables, 4 refs

R.L. Ryan and S. Mall
Scattering of an Elastic Wave by a Sub-Surface Elastic Fiber
J. Appl. Mech., Trans. ASME, 51 (1), pp 199-204 (Mar 1984) 1 fig, 1 table, 11 refs

Z.-M. Ge and X.-X. Wu
The Stability of Motion of a Rigid Body about a Fixed Point in the Case of Euler with Damping Torque
J. Appl. Mech., Trans. ASME, 51 (1), pp 198-199 (Mar 1984) 1 ref

A. Bhimaraddi and L.K. Stevens
A Higher Order Theory for Free Vibration of Orthotropic, Homogeneous, and Laminated Rectangular Plates
J. Appl. Mech., Trans. ASME, 51 (1), pp 195-198 (Mar 1984) 4 tables, 9 refs

CALENDAR

SEPTEMBER 1984

3-6 AGARD Specialists' Meeting on "Transonic Unsteady Aerodynamics and Its Aeroelastic Applications" [AGARD/SMP] Toulouse, France *(Dr. James Olsen, AFWAL/FIB, Wright-Patterson Air Force Base, OH 45433 - (513) 255-5723)*

9-11 Petroleum Workshop and Conference [ASME] San Antonio, TX *(ASME Hqs.)*

10-13 Third National Conference and Workshop on Environmental Stress Screening of Electronic Hardware [IES] Philadelphia, PA *(IES Hqs.)*

30-Oct 4 Power Generation Conference [ASME] Toronto, Ontario, Canada *(ASME Hqs.)*

OCTOBER 1984

1-3 Army Symposium on Solid Mechanics [Army Materials and Mechanics Research Center] Newport, RI *(Army Materials and Mechanics Research Center, Arsenal Street, DRXMR-SM, Watertown, MA 02172 - (617) 923-5259)*

7-11 10th Design Automation Conference and 18th Mechanisms Conference [ASME] Cambridge, MA *(Prof. Panos Papalambros, Mechanical Engineering and Applied Mechanics, The University of Michigan, Ann Arbor, MI 48109 - (313) 763-1046)*

8-12 Acoustical Society of America, Fall Meeting [ASA] Minneapolis, MN *(ASA Hqs.)*

9-11 13th Space Simulation Conference [IES, AIAA, ASTM, and NASA] Orlando, FL *(Institute of Environmental Sciences, 940 E. Northwest Hwy., Mt. Prospect, IL 60056 - (312) 255-1561)*

15-18 Aerospace Congress and Exposition [SAE] Long Beach, CA *(SAE Hqs.)*

17-19 Stapp Car Crash Conference [SAE] Chicago, IL *(SAE Hqs.)*

22-24 ASME/ASLE Lubrication Conference [ASME/ASLE] San Diego, CA *(ASLE Hqs.)*

22-25 Symposium on Advances and Trends in Structures and Dynamics [George Washington University and NASA Langley Research Center] Washington, DC *(Prof. Ahmed K. Noor, Mail Stop 246, GWU-NASA Langley Research Center, Hampton, VA 23665 - (804) 865-2897)*

23-25 55th Shock and Vibration Symposium [Shock and Vibration Information Center, Washington, DC] Dayton, OH *(Dr. J. Gordan Showalter, Acting Director, SVIC, Naval Res. Lab., Code 5804, Washington, DC 20375 - (202) 767-2220)*

DECEMBER 1984

3-5 International Conference on Noise Control Engineering [International Institute of Noise Control Engineering] Honolulu, Hawaii *(William W. Lang, Chairman, INTER-NOISE 84, P.O. Box 3469, Arlington Branch, Poughkeepsie, NY 12603)*

3-6 Truck and Bus Meeting and Exposition [SAE] Detroit, MI *(SAE Hqs.)*

9-13 ASME Winter Annual Meeting [ASME] New Orleans, LA *(ASME Hqs.)*

FEBRUARY 1985

25-Mar 1 International Congress and Exposition [SAE] Detroit, MI *(SAE Hqs.)*

MARCH 1985

18-21 30th ASME International Gas Turbine Conference and Exhibit [Gas Turbine Division of ASME] Houston, TX *(International Gas Turbine Center, Gas Turbine Division, ASME, 4250 Perimeter Park South, Suite 108, Atlanta, GA 30341 - (404) 451-1905)*

APRIL 1985

8-12 Acoustical Society of America, Spring Meeting [ASA] Austin, TX *(ASA Hqs.)*

15-19 2nd Symposium on The Interaction of Non-Nuclear Munitions with Structures [Tyndall AFB, FL; Eglin AFB, FL; and Kirtland AFB, NM] Panama City Beach, FL *(Ms. L.C. Clouston, Registrar, P.O. Box 1918, Eglin AFB, FL 32542 - (904) 882-5614)*

MAY 1985

6-9 American Society of Lubrication Engineers, 40th Annual Meeting [ASLE] Las Vegas, NV *(ASLE Hqs.)*

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AHS: American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics
1633 Broadway
New York, NY 10019

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASLE: American Society of Lubrication Engineers
838 Busse Highway
Park Ridge, IL 60068

ASME: American Society of Mechanical Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

ICF: International Congress on Fracture
Tohoku University
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IMechE: Institution of Mechanical Engineers
1 Birdcage Walk, Westminster,
London SW1, UK

IFToMM: International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
67 Alexander Dr.
Research Triangle Park, NC 27709

SAE: Society of Automotive Engineers
400 Commonwealth Dr.
Warrendale, PA 15096

SEE: Society of Environmental Engineers
Owles Hall, Buntingford, Hertz.
SG9 9PL, England

SESA: Society for Experimental Stress Analysis
14 Fairfield Dr.
Brookfield Center, CT 06805

SNAME: Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE: Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC: Shock and Vibration Information Center
Naval Research Laboratory
Code 5804
Washington, D.C. 20375

PUBLICATION POLICY

Unsolicited articles are accepted for publication in the **Shock and Vibration Digest.** Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in DIGEST articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the example below.

> Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].

> Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that . . .

The format and style for the list of References at the end of the article are as follows.

- each citation number as it appears in text (not in alphabetical order)
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- abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)
- volume, number or issue, and pages for journals; publisher for books
- year of publication in parentheses

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter - A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).
2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addison-Wesley (1955).
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5. Landahl, M., Unsteady Transonic Flow, Pergamon Press (1961).
6. Miles, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," J. Aeronaut. Sci., 23 (7), pp 671-678 (1956).
7. Lane, F., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," J. Aeronaut. Sci., 24 (1), pp 65-66 (1957).

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